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JOURNAL OF ECONOMIC ENTOMOLOGY
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# DDT to Control Insects Affecting Man and Animals in a Tropical Village

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During March and April 1946 I applied 2200 pounds of a 50-per cent DDT wettable powder as a spray to buildings and on animals in the isolated bauxite-mining village of Moengo, Surinam, South America, to reduce the mosquito incidence.

This village of 1500 people is located at the northeastern edge of a slightly elevated strip of sandy and clay soil about 20 miles inland from the sea and parallel to it across northern Surinam, and is surrounded by virgin jungle. The village is located on a bauxite ridge about 30 feet above sea level. The houses are elevated from a foot or 2 to 6 or 7 feet above the ground to keep them dry, to prevent termite damage, and to allow free circulation of air. Underneath the houses there is crushed bauxite. Precipitation in the locality is heavy, averaging about 92 inches annually. Slightly over one-third of the rainfall occurs during the period of April through June. The driest months are September, October and November, during which time only about 12 inches of rain falls. The temperature is fairly constant and usually ranges from the upper sixties to the lower nineties. The coolest month is February; the warmest period is during the dry months. The relative humidity averages about 84 per cent.

DDT FORMULATION AND EQUIPMENT USED.—A 2.5-per cent DDT suspension prepared by diluting 50-per cent DDT wettable powder in water was used as a spray on approximately 100 milk cows, calves, and a few donkeys, and as a dip on about 90 dogs. This formulation was also used as a residual spray on farm buildings, bunk houses, stores, on huts of thatch and rough lumber, and on the interior of the 3-room house in which I lived (Fig. 1). This house was lined with wallboard painted white with green trimmings, and the DDT suspension presented an unsightly appearance on these surfaces. The under side of the flooring and the grave

FIG. 1.—The house in which the author lived in Moengo. The interior of the apartment at the right was sprayed with a 2.5 per cent wettable DDT spray which continued to kill all mosquitoes within 8 hours, as long as 11 months after treatment.

underneath all the houses in the village were sprayed with the DDT suspension. All the attics were also treated.

A 5-per cent DDT oil solution was used inside the houses and in the hospital, where the appearance of the DDT suspension would have been objectionable. Screens were sprayed from both inside and outside.

In so far as possible, every square foot of surface, both inside and outside, the buildings, was treated, and every cow, donkey, and dog within the village area was sprayed or dipped. Three isolated calves were excepted, because they were used regularly as bait in stable traps to estimate mosquito populations.

The oil spray was used at the rate of about 1 gallon to each 1000 square feet of

[1] Acknowledgment is made of the excellent cooperation and aid given in this work by Frank B. Cuff, Roy F. Miller, George W. Streepey, I. R. J. de Greve, I. Guicherit, Fred J. Wassenborg, C. R. Corr, and William Asgerali, of Surinaamsche Bauxite Maatschappij (Surinam Bauxite Company), and by D. C. Geijskes, Agricultural Experiment Station, Paramaribo, Surinam.

surface, and the suspension at about 1 gallon to each 300 square feet. Our intention was to wet the surface thoroughly with large droplets of spray without allowing the liquid to run off.

Three wheelbarrow sprayers, two operated by gasoline motors and one by hand, and each with 200 feet of oil-resistant hose, were used almost daily for about 5 weeks. Although the motor-driven sprayers had automatic agitators, we found it desirable to stir the DDT suspension constantly so that the heavy powder would not settle to the bottom of the tank. Nozzles producing a flat, fan-shaped spray were used. We were careful to keep the mixtures free of dirt and debris so as not to clog the nozzles. When this was done we had no trouble applying the suspension.

EFFECTIVENESS AGAINST MOSQUITOES.—The complete analysis of a considerable amount of data on the mosquito population[2] before and after treatment will be reported elsewhere. Unfortunately, we have records of the mosquito population before treatment only for the 2 weeks previous to the spraying. However, we do have considerable data on mosquito populations after the treatment at five different ecological sites in and around the village and in one untreated site about 30 miles distant. This information was gained by means of (1) a stable trap, (2) a rotary trap, (3) a cone on an automobile fender, (4) a New Jersey light trap, and (5) collections on two men for 2 nights at each site each month, except October, from March 1946 through February 1947.

The most conspicuous reduction in the mosquito population was observed in the vicinity of the cow barns, where 60 milk cows and a dozen calves were sheltered each night. For several nights before the animals and walls were sprayed, we counted hundreds of engorged mosquitoes resting on the lower part of the walls inside the barns after dark. Of these, roughly 10 per cent were anophelines. Within 2 weeks after treatment we found it difficult to locate a single mosquito in the corners where hundreds had rested before. In May, about 10 weeks after the spraying, 152 mosquitoes (10 anophelines) were collected on the lower part of the barn walls by 2 men who captured all the mosquitoes seen.

In the center of the village the mosquitoes caught in a light trap dropped from about 900 and 400 in 2 nights' collections before treatment to 13 and 3, respectively, a few days after treatment. Later there were even fewer mosquitoes in spite of the discontinuance of all other mosquito-control measures, such as treating the water moats around the base of the foundation pillars where *Culex quinque fasciatus* had been breeding in large numbers.

In and around one of the ecological sites, where the breeding grounds were large and where there were no buildings and no animals within a half-mile, there was no drop in the mosquito population. In fact, 10 weeks later during the rainy season in May and June the collections at this site increased 200 to 300 per cent.

After I had sprayed the house in which I lived with DDT suspension, several hundred living mosquitoes were liberated in the house several times in the morning. For the first 2 or 3 months after treatment these mosquitoes would be found dead or dying on the floor after 3 or 4 hours' exposure to the DDT residue.

In February 1947, 11 months after treatment, 2000 mosquitoes were released in this house at 9 A.M. Eight hours later no living mosquitoes could be found except for those on sheets spread on the floor, which showed characteristic DDT tremors. At the same time 2000 mosquitoes were placed in an identical house that had been sprayed with an oil solution containing 5 per cent of DDT. Eight hours later several mosquitoes were found on the floor with characteristic DDT tremors but most of them were alive and apparently unaffected. Twenty-four hours later dozens of living mosquitoes could still be seen on the walls and ceiling, and after 50 hours two living mosquitoes were seen which showed no signs of DDT poisoning. In June 1947, 15 months after treatment, the DDT suspension residue was still killing 60 per cent of the introduced mosquitoes in 7 hours.

EFFECTIVENESS AGAINST FLIES.—In March 1946 we observed a great number of horn flies on the cattle and house flies in the dairy barns. Flies were also numerous in and about the houses in the village a half-mile distant. These flies were

[2] *Anopheles aquasalis* Curry, *A. oswaldoi* (Pery.), *A. pessoai* G. and L., *A. goeldii* R. and G., *Mansonia albicosta*, (Chagas), *M. titillans* (Walk.), *Culex quinquefasciatus* Say, *C. nigropalpus* Theob., *Aedes taeniorhynchus* (Wied.), *A. scapularis* (Rond.), *Aedeomyia squamipennis* (L. and A.), *Uranotaenia lowii* Theob., and others. All identifications by Alan Stone, Bureau of Entomology and Plant Quarantine.

breeding on the floor of the barns in manure and green grass bedding, which was added in layers day by day and which was not cleaned out more than once a month. There were no gutters in the floor, and when I first saw the barns an accumulation of manure and grass bedding a foot deep was literally crawling with fly larvae. Our first operations began here, and within 10 days after the barns had been cleaned and the cows and the barn walls sprayed with DDT the fly population in the village and in the barn was almost eliminated. The same condition prevailed when I inspected the barns 10 months later. Although the cows were sprayed each month during that time with about 2 quarts each of DDT suspension, the barn had not been sprayed again. However, it had been cleaned and the manure spread over the fields daily. I believe that horn flies have been eradicated in Moengo and it is now difficult to find house flies.

EFFECTIVENESS AGAINST COCKROACHES.—In March 1946 American cockroaches were generally numerous in some of the houses and in one of the stores. After all the furnishings had been removed from one house, it was thoroughly sprayed with 5 per cent DDT in oil. Within an hour more than 500 dead cockroaches were counted on the floor, which was approximately 25 feet square. Several cockroaches ran off the floor of the house and were eaten by chickens. Although some of the chickens showed signs of DDT tremors the next day, none died and 2 days later all appeared normal.

In February 1947 the house was treated again with the same technique and material as in 1946. After this treatment fewer than 50 dead cockroaches were found. Elsewhere in the village, in places where heavy infestations were seen in 1946, there was still a reduction of about 90 per cent as a result of the single treatment that had been applied 10 months previously.

EFFECTIVENESS AGAINST BEDBUGS.—There were only a few infestations of bedbugs in Moengo in 1946, and these were comparatively light. In 1947 we visited all the places previously infested but found no evidence of bedbugs. Later we sent a notice to each householder offering a cash reward to anyone bringing us a living bedbug from a place sprayed with DDT in 1946. None were submitted.

EFFECTIVENESS AGAINST FLEAS.—Of the 90 dogs dipped in the DDT suspension in 1946, there were only 3 or 4 on which no fleas could be found previous to treatment, and these had been treated with flea preparations before March of that year. Our original intention was to dip the dogs at monthly intervals, but after one dipping 30 days after I left Moengo only a few dogs were given further treatment. On a number of dogs examined in February 1947 the flea population was still high, and practically all the animals were infested.

EFFECTIVENESS AGAINST CATTLE TICKS.—Ticks are not particularly numerous in the vicinity of Moengo, although one or two are found on workers at the end of each day's work in the field. In March 1946 the 60 cattle were examined, and there were about a dozen *Boophilus annulatus microplus* Can.[3] on the upper part of each cow's udder. Eight days after the cows were sprayed we found 1, 2, or none on each animal. During the dry season, when ticks are more numerous, the monthly counts were higher although they never reached an average of more than 5 or 6 per animal. In January 1947, after the cattle had been sprayed 11 times at intervals of 30 days, I found 1 tick on the udder of one of the 60 animals. Three calves that had been isolated and had not been sprayed had 7, 9, and 10 ticks.

EFFECTIVENESS AGAINST FOWL TICKS.—Practically every family in Moengo has a small chicken coop where a few nondescript hens and chickens are kept. The coops are usually dirty, and a few were found to be heavily infested with fowl ticks, *Argas persicus* (Oken). No mites were observed. Apparently the fowl tick was eradicated in Moengo, because after chicken coops were sprayed no living ticks could be found. A careful inspection made in 1947 revealed the same result.

EFFECTIVENESS AGAINST CHIGOES.—The following three statements regarding chigoe infestations before and after treatment of the bauxite under the houses were made by a physician, a mining engineer, and a foreman of the mining company.

(1) "*Tunga penetrans* (*Dermatophilus penetrans*), the chigoe, here called sika, was very numerous in Moengo. I do not

[3] Determination by F. C. Bishopp, of the Bureau of Entomology and Plant Quarantine.

have figures at hand, but since I have been here 4.5 years, I feel able to express my personal opinion on the frequency of this minor tropical affliction. Before the all-out DDT spraying we had many cases. Practically not a day passed without a call for aid in extracting these pests. I once removed 15 sikas in one day from the legs of a staff member. Children in the village were far more affected than the adults, especially on the toes. Since the extensive DDT treatment, now 10 months ago, I have not been able to diagnose one single case of *Dermatophilus penetrans*."

(2) "Before the DDT experiment in Moengo, Surinam, I and my dog were bothered very much with sand flies or sikas. Since my house and the ground under and around my house was sprayed with DDT in March 1946, neither I nor my dog has had one sand flea or sika."

(3) "Since October 1937, when we became residents of Moengo, my family has been infested by chigoes, locally called sikas or sand flies, which infest the dry gravel under and around my elevated house. Although we tried to control them, not a week passed when my wife did not have to remove the egg bags of these insects from under the skin of toes and fingers of our four children and ourselves. During the dry season they were more numerous, and often one person had as many as eight of them. On March 28, 1946, my house was treated with DDT. The area under the floors and the gravel under and around the house were sprayed with a 2.5 per cent suspension of a wettable powder consisting of 50 per cent DDT. Although since treatment with DDT we have passed the big and the little dry season, we have not had a single chigoe infestation in our family. Several other residents of Moengo have told me, unsolicited, the same experience."

EFFECTS OF TREATMENT ON WILDLIFE.—Several dead toads, frogs, and small snakes were found near the houses, within a day or two after treatment. It is presumed that they were killed by the DDT sprays. In the attic of one house 17 bats were killed by the treatment within 24 hours. No song birds were affected, so far as is known.—8-15-47.

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# DDT to Control *Anopheles farauti* on Espiritu Santo, New Hebrides Islands[1]

HAROLD R. YUST[2]

*Anopheles farauti* Lav. is an important insect vector of human disease on the island of Espiritu Santo, New Hebrides, and the only known *Anopheles* in the New Hebrides Islands. It is probably the only vector of malaria and is the most important carrier of filariasis. A very high incidence of malaria exists in the inhabitants of the island. A survey of Melanesian natives in one village showed 52 per cent with positive blood smears. Planters on the island have told the writer that passengers on supply ships visiting the island before the war would not go ashore because of the fear of contracting malaria. Such was the reputation of the island.

Gravid *Anopheles farauti* females, and larvae in all developmental stages, are found throughout the year due to the favorable tropical climate. Oviposition continues during the cooler months of May through August. Larval development occurs in road ruts, puddles, rivers, streams, ponds, lakes, wild hog wallows, animal hoof prints, taro gardens and open wells, to name but a few sites. Daggy (1945) states that 90 per cent of all breeding resulted from military activity, primarily road ruts created by military vehicles. The period from oviposition to emergence of the adults is about 12 days during the summer months.

Although the adults of this species are quite wild, they enter dwellings and native huts at night. After obtaining a blood meal in a native hut the mosquitoes tend to rest on objects in the hut, on the woven bamboo walls and in the roof thatching. These surfaces offer excellent adult resting and hiding locations. During the day-

[1] U. S. military troops landed on Espiritu Santo in 1942. It was an advance military base thereafter until the end of World War II. The writer was stationed on the island for eighteen months arriving in October 1943. During this time he was an entomologist with the Base Malaria and Epidemic Control organization.

[2] Lieutenant, H(S), USNR. On military leave from the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

light hours the adults usually leave open huts but if the interior is dark and little air movement or commotion exists, many adults do not leave the huts. During the day adults are found also on wet tree buttresses in deep jungle shade, in hollow logs, in tree holes, in open wells and in natural caves.

Mosquito abatement was instituted by military authorities as a malaria control measure, but early in 1943, before the program was effective, over 400 primary malaria infections of military personnel were recorded on the island during January and about the same for February. An effective abatement program was later developed which was directed primarily toward control of *Anopheles farauti* but other existing mosquitoes reported by Perry (1946) were controlled. The program consisted primarily of weekly spraying of water suitable for larval development within and at least a mile beyond camp, spraying plantation buildings and dwellings in the area for adults, daily spraying of military quarters, draining and filling water basins, and establishing surface feeding fish (*Gambusia* sp.) where appropriate. The larvicide was usually No. 2 diesel oil when available and in limited cases a paris green spray. Pyrethrum was applied with hand spray guns or aerosol bomb for adults. The program resulted in a drastic decrease in the *A. farauti* population and a corresponding reduction in the incidence of malaria in the military troops. Education in protective measures, rigid malaria discipline, screened quarters, and atabrine treatment of the natives among other things, were also very important in reducing new infections.

DDT became available in limited quantities for mosquito control in April 1944. Since word was received of the work by Gahan *et al.* (1945) with DDT as a residual type treatment for certain adult mosquitoes, preliminary cage tests were made which indicated that the spray residue was quite toxic to *Anopheles farauti*. It seemed likely that the best possible use of the limited supply was for the control of adults in plantation buildings and native huts in the military area because troops visited the native villages and adults continued to be found, especially in native quarters in spite of existing control measures. DDT was applied in native

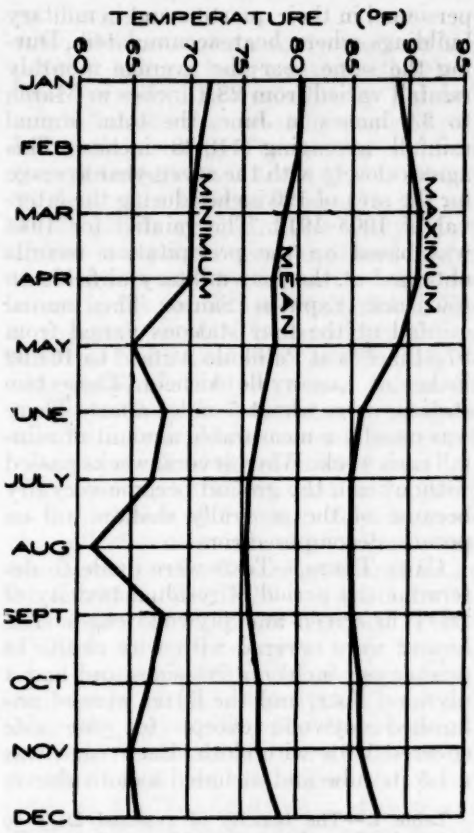


FIG. 1.—The monthly mean, maximum and minimum temperatures at Pekoa Airfield on the southeast corner of Espiritu Santo, New Hebrides.

huts to determine its effectiveness. DDT solutions were subsequently tested as a larvicide and compared with No. 2 diesel oil. This paper describes some of the tests with DDT against *A. farauti* and some of the uses of DDT in its control on the island. It is also a record of the effective mosquito control obtained on an advanced military island base in the South Pacific during World War II.

CLIMATIC CONDITIONS.—Records of open shade temperatures during 1944 were obtained from the military meteorological unit stationed at Pekoa Airfield on the southeast corner of Espiritu Santo. The temperatures ranged from 61° F. in in August to 92° F. in March and the monthly means (average daily maximum-minimum for month) ranged from 75.5° to 80.5° F. The monthly mean, maximum and minimum temperatures are plotted in figure 1. The maximum temperatures are lower than those experienced by military

personnel in their quarters and in military buildings where heat accumulated. During the same year the average monthly rainfall varied from 28.1 inches in March to 3.2 inches in June, the total annual rainfall averaging 118.28 inches. This agrees closely with the seven-year average for the area of 120 inches during the interval of 1905–1912. The rainfall for 1944 was based on the precipitation records obtained at the four military airfields on southeast Espiritu Santo. The annual rainfall at the four stations varied from 97.31 inches at Pallikulo Airfield to 161.99 inches at Luganville Airfield. These two stations were about 7 miles apart. There was usually a measurable amount of rainfall each week. When several weeks passed without rain the ground became very dry because of the generally shallow soil on porous, decomposed coral.

CAGE TESTS.—Tests were made to determine the period of residual toxicity of DDT in screen and plywood cages. The former were covered with wire cloth (18 meshes per inch) on five sides and had a plywood floor, and the latter were of unfinished plywood except for one side covered with wire cloth. Each cage was a 1.5 ft. cube and included a cloth sleeve.

**Table 1.—The toxicity of residual DDT to *Anopheles farauti* exposed continuously in cages at various intervals after treatment.**

| Days after Treatment | Knock-down Time, Minutes | | Killing Time, Minutes | |
|---|---|---|---|---|
| | Average | 100 Per Cent | Average | 100 Per Cent |
| 13 | 30.7±2.1 | 44 | — | — |
| 33 | 43.6±2.8 | 85 | 163.0±18.5 | 310 |
| 38 | 47.2±1.8 | 70 | 175.7±12.0 | 325 |
| 46 | 45.3±2.8 | 75 | 201.2±25.0 | 425 |
| 75 | 55.0±3.3 | 89 | 251.6±17.6 | 410 |

A screen and a wooden cage were treated with a 5 per cent DDT solution in kerosene giving a DDT deposit of approximately 180 mg. per square foot. During the interval of the tests the cages were stored in a Quonset-type hut with side, screened openings the full length of the building. Ten blooded females were released in each cage at irregular intervals after treatment and were exposed continuously until they were prostrate. The *Anopheles farauti* adults were captured in native huts outside of the military area. The knockdown and killing times, in minutes, were recorded. The results are summarized in table 1.

The *Anopheles farauti* mosquitoes for the test 1 day after treatment did not survive a tropical rain storm during the trip to the laboratory and females of *Culex annulirostris* Skuse were substituted because they were available in the camp area. *C. annulirostris* were also included in a test 13 days after treatment. The average knock-down time, in minutes, at 1 and 13 days, was 44.8 ± 2.4 and 73.0 ± 4.5, respectively. The knock-down time increased substantially in 13 days. The DDT residue was effective over the 2.5 months period of the test. The press of other duties prevented its continuation. The results in the screen and wooden cages were approximately the same at each interval. Over the entire period the average knock-down time in the screen cage was 46.0 minutes and in the wooden cage was 43.6 minutes. The killing time averaged 203.4 and 201.1 minutes, respectively, showing comparable results on the two surfaces.

The influence of weathering on the DDT residue was observed simultaneously with the above test. A treated screen cage was placed in the covered, open end of a Quonset-type hut. It was protected from direct sunlight and from rain, except for water blown in during severe rain storms. The location was comparable to the screens along the sides of the huts. The knock-down time in the cage one day after treatment was similar to that in the other two cages, suggesting the same DDT deposit. The knock-down time at 13, 38, and 75 days, averaged 62.1, 134.5, and 449.6 minutes, respectively. These results may be compared with those in table 1. The average knock-down time in the exposed cage after 13 days was higher than that in the unexposed cages after 75 days. No blowing rain storms occurred during the 13 days. The reduction in toxoicity due to weathering was significant because it indicated that painting the screens with DDT solution was of value only if done at frequent intervals. It was not practical to treat all quarters and buildings of a large base at required intervals. This conclusion was verified when the mess hall screens were painted for fly control.

The susceptibility of *Anopheles farauti* was compared with that of two other prevalent species of mosquitoes, namely, *Culex annulirostris* Skuse and *Aëdes hebri-*

*deus* Edw. The unexposed screen cage was used 75 days after treatment. Twenty adults were included in each test. The mosquitoes were not removed from the cage until they were prostrate. The results are presented in table 2.

**Table 2.—Comparative susceptibility of *Anopheles farauti, Aëdes hebrideus* and *Culex annulirostris* to residual DDT on a screen wire cage.**

| Species | Knock-down Time, Minutes | | Killing Time, Minutes | |
|---|---|---|---|---|
| | Average | 100 Per Cent | Average | 100 Per Cent |
| *A. farauti* | 52.2± 3.5 | 79 | 235.8±22.8 | 395 |
| *A. hebrideus* | 52.7± 3.7 | 84 | 220.6±14.5 | 350 |
| *C. annulirostris* | 108.4±10.1 | 240 | 349.2±22.0 | 610 |

The *Anopheles* and *Aëdes* mosquitoes were similar in susceptibility and much more susceptible than the *Culex* as indicated by both knock-down and killing time. In a previous test it was shown that *C. annulirostris* was more difficult to kill than *A. farauti*. In other cage tests prevalent flies, including *Sarcophaga* sp., *Ophyra* sp. and *Chrysomyia* spp., were shown to be more susceptible to residual DDT than *A. farauti*.

HUT TESTS.—The effectiveness of residual DDT in native huts was observed in many native villages outside of the mosquito controlled area where *Anopheles farauti* were abundant. In a typical treatment the entire interiors of seven huts were treated, including bed nets when present. Two solutions were used, namely (1) 20 per cent DDT in xylene and (2) 5 per cent DDT in kerosene. The first solution contained 20 per cent emulsifying agent and was applied in two huts at the rate of 100 mg. of DDT per square foot. The 5 per cent DDT in kerosene was applied at the rate of 45 mg. and 180 mg. per square foot. Two huts were treated with the former deposit and three with the latter.

Before treatment the average *Anopheles farauti* catch in 10 minutes by two men was 73 per hut. Inspections were made during the day in the treated and the untreated huts at irregular intervals over a period of 3 months. No live mosquitoes were found in treated huts during 93 days, except one live *A. farauti* which was found inside a bed net in the inspection 76 days after treatment. Subsequent investigation disclosed that the lone mosquito was under a newly acquired bed net that had not been treated with DDT. This survivor had undoubtedly pursued a native under the net as he was going to bed in the evening. The average catch in the untreated huts at 1, 22, 45, 59, 76, and 93 days after treatment was 72, 75, 53, 50, 33, and 24, per hut, respectively. Most of the mosquitoes were captured under the bed nets used by the natives. The decrease in the population was undoubtedly a seasonal trend. The application was made in May, 1944 which is the beginning of the relatively dry, cool season. In January, 1945, the population was again substantially higher in several untreated villages outside of the controlled area.

Ten per cent DDT in dust was applied in the interior of five huts to determine the effectiveness of this formulation which was received in large quantities in 2-ounce cans. The DDT was applied with a hand dust gun (plunger type) at the rate of about 30 mg. per square foot. Inspections for *Anopheles farauti* were made at irregular intervals in the treated huts and in nearby untreated huts. Before treatment *A. farauti* adults were collected at the rate of 68 per hut. Inspections were made at 21, 78, and 92 days after treatment. No live mosquitoes were found until the last inspection when two were taken. The catch in the untreated huts during the corresponding inspections averaged 120, 10, and 25, respectively. It appears that a relatively light application of DDT dust was effective for 2.5 months in native huts. The roof thatching and woven bamboo walls provide excellent surfaces to hold a dust insecticide and native women do not disturb dust deposits in their huts. DDT dust therefore is a practical mosquito control measure for the natives although an excipient that prevents caking at high humidities is necessary. The powder is not a fire hazard and could be applied by the natives for their own protection under the supervision of missionaries.

PRACTICAL ADULT CONTROL.—Because of the effectiveness of DDT residues against *Anopheles farauti*, all native huts and plantation buildings in and adjacent to the controlled areas were sprayed regularly as a part of the mosquito abatement program. A 5 per cent solution in kerosene was applied at the rate of 1 gallon per 1000 square feet in most cases but

a 10 per cent water solution was used in some of the planters' residences. The former was applied with cylindrical knapsack sprayers and the latter with *Flit gun* type hand sprayers. The treatment was applied at intervals of 3 months. About 500 gallons of 5 per cent DDT in kerosene were required for complete treatment of plantation buildings and native huts. Almost without exception the cooperation of planters and natives was readily obtained.

Night and day inspections for adults were made each week as a regular phase of the mosquito control program. In the month of June 1944 prior to treatment some adults were found in the camps of three military units and in living quarters of six plantation villages. After the first complete application in early July, no *Anopheles farauti* adults were found in the controlled area during the remainder of 1944 but two adults were found during January 1945 in a military camp along the Sarakata river. Also *Aëdes aegypti* (L.), vector of dengue fever, was not found in the area after August, although it was collected in military camps or plantation villages during each month prior to this time.

Mosquito control in native and plantation villages was very important in malaria control. Military personnel would visit the villages out of curiosity although they were "off limits." The danger of malaria infection associated with the villages may be illustrated by an example. Seventeen men on a pleasure and sightseeing trip spent a night in an untreated village on an adjacent island. Seven malaria infections were attributed to the overnight trip.

The screens and interiors of military quarters and buildings at outposts were treated with a 5 per cent DDT solution in kerosene as often as necessary. It was applied by outpost personnel on screens with a 4-inch paint brush at the rate of about one gallon per 1000 square feet. This deposit resulted when about half the screen interstices were filled with liquid during application. It afforded excellent protection against both flies and mosquitoes, and was a practical, effective measure where relatively few quarters were located in an area with a limited larval control program.

LARVAL CONTROL.—The effectiveness of DDT in No. 2 diesel oil against *Anopheles farauti* larvae was determined in a series of tests. Since water in vehicle ruts provided the greatest problem in larval control, tests were made in water-filled ruts of abandoned roads. The water was several inches to a foot deep and vegetation was usually growing along the margin of the water. A 2.5 per cent solution was tested at the rate of 0.5, 1.0, 1.5, 2.0, and 10 gallons per acre. The first application was with a hand sprayer and the last four with a knapsack sprayer. The larval population in each plot was lower a week after treatment. With the two lightest applications appreciable numbers of larvae were present a week later but with the last three no larvae were found. With 10 gallons of No. 2 diesel oil (without DDT) larvae were present a week after treatment. With 10 gallons of 2.5 per cent DDT per acre, the residual effect prevented breeding for 2 weeks but larvae were present 3 weeks later.

A 5 per cent solution of DDT in No. 2 diesel oil was applied on water in road ruts and swamps within the controlled area with a hand sprayer at the rates of 1 and 2 quarts per acre. In a typical treatment with 1 quart per acre larvae were collected in 255 dips at the rate of 12.9 per 100. Two days after application no larvae were found but 6 days later larvae were collected in 225 dips at the rate of 56 per 100 dips. Nearly all of the larvae in the latter inspection were in the early instars but the population was higher a week after treatment. In a number of test applications at the rate of 2 quarts per acre no larvae were collected 2 days later but in a week larvae were usually found in limited numbers—fewer than before treatment. Residual toxicity with this dosage was no greater than with No. 2 diesel oil. The indications were that weekly applications of 2 quarts or more per acre of 5 per cent DDT were necessary for satisfactory control.

DDT was used as a larvicide in limited areas for regular control by the end of June. A 5 per cent solution in No. 2 diesel oil was applied each week with a hand sprayer. The hand sprayers first provided had less than one-quart capacity, were often defective, and were generally unsatisfactory, but they were used because no others were available. Eventually a good, continuous operating, 3-quart

sprayer with a substantial pump and adjustable outlet was available. By the end of the year most of the larval control by foot was with 5 per cent DDT in No. 2 diesel oil. This treatment produced better control than diesel oil alone applied with a knapsack sprayer because better distribution of the larvicide was obtained on water surfaces and more complete treatment of all water catchments resulted. The latter was true because the applicator was less burdensome to the operator resulting in more thorough exploration of the area for water catchments. A full 3-quart sprayer usually lasted half day because the breeding sites generally were small and widely scattered. Residual toxicity was not obtained with this dosage and generally could not be utilized because of the constant creation of new breeding sites by rains and military operations. Because new water catchments were constantly being formed, weekly coverage of the controlled area by spray squads was imperative.

Heavy applications of 5 per cent DDT were made for their residual action where certain confined water was not disturbed and where the destruction of all aquatic life was of no importance. An example was an old Construction Battalion logging trail which was sprayed with 40 gallons of 5 per cent DDT with a knapsack sprayer on May 25. This was the usual amount of No. 2 diesel oil applied weekly with a knapsack sprayer. The trail was impassable because of deep ruts. Before treatment 101 *Anopheles farauti* larvae were collected in 316 dips. Weekly inspections were made for several months after treatment and twice monthly thereafter. No *A. farauti* larvae were collected until January 1945, more than seven months after treatment. At the end of 1 week all aquatic insects in the water were dead and many dead adult mosquitoes were floating on the surface. At 14 days, no live insects were found in the water and at 21 days only two live members of the family *Corixidae* were observed. At 28 days, *Corixidae*, *Notonectidae*, *Dytiscidae*, and *Odonata* nymphs, were present in small numbers.

Other DDT applications were made under a variety of conditions. Five per cent DDT in diesel oil was mixed with sawdust and broadcast by hand in shallow water containing vegetation. This treatment was effective in the control of larvae in wet weather swamps and low flat areas that flood during protracted rains. Bags filled with sawdust soaked with 5 per cent DDT in oil were submerged for continuous application of larvicide. Small DDT bags lasted as long and were just as effective as those with oil alone that were five times or more larger. Ten per cent DDT dust was mixed with sawdust and applied in shallow streams containing watercress used for food. The sawdust held the DDT on the water surface. The treatment controlled mosquito breeding but did not damage the watercress which was used in salads by planters operating restaurants for military patronage. Men on larval inspection squads, who covered the entire controlled area twice monthly, carried 2-ounce cans of DDT dust. When occasional hoof depressions and small holes were found with larvae, they were treated immediately with a liberal application. DDT dust was not generally used because frequent rains and the prevailing high humidity often wet the powder and applicator and caused clogging of the dusting equipment.

Considerable DDT spraying was done by a small airplane at the rate of 2 quarts per acre. A satisfactory spraying apparatus for a small airplane is described by Yust (1946). Application by airplane was usually restricted to a period from sunrise to 10:00 A.M. when air movement was negligible and before the air became rough at treetop levels. Areas especially inaccessible by foot and those requiring many man hours to cover such as swamps, lakes, ponds, rivers, streams, long drainage ditches including the spoil banks, logging areas, abandoned military roads and plantation roads were sprayed. An area of about 50 acres in which logging operations were conducted was completely sprayed to prevent breeding in ruts created by heavy equipment. Breeding occurs in dense mats of filamentous green algae along the river banks or attached to aerial tree roots. Airplane spraying simplified control of breeding in the algae mats. An Army combat division during staging and training operations created many ruts and holes in a section of jungle. Approximately 5000 *Anopheles farauti* larvae were collected in resulting pools in 500 dips. The area was sprayed by airplane and several days later larvae were

found in only one pool which undoubtedly had not been covered with insecticide. The swamps and large permanent bodies of water are readily seen from the air and do not require markers for the pilot to locate them. Jungle roads, drainage ditches and streams were frequently difficult to see from the air due to a continuous forest canopy. To mark obscure breeding sites 30-inch meteorological balloons filled with hydrogen were suspended in the air at treetop level. The balloons were excellent markers. The jungle canopy filtered out considerable insecticide but several runs giving an application of 1 gallon per acre usually controlled breeding in water overgrown with trees.

DISCUSSION.—Inspections during 1944 failed to reveal *Anopheles farauti* adults in the controlled area after DDT was used. Prior to this they were found in the area each month. The larval population also decreased. In 42,525 sampling dips made by the larval inspection squads on Espiritu Santo during October 1944, only 20 larvae were obtained, giving a rate of 0.05 larvae per 100 dips. The highest population for the year was in May when 1456 larvae were collected in 38,701 dips giving a rate of 3.8 per 100 dips. Even the latter population was very low considering that 1 to 5 larvae per dip were not uncommon in the adjacent uncontrolled area. Before DDT was available, *Flit-gun* type hand sprayers were used to apply pyrethrum against adults, and knapsack sprayers to apply larvicide oil. With DDT the use was reversed; the former was used for larval control and the latter for adult control. The average military strength on Espiritu Santo and small adjacent islands during 1944 was slightly above 40,000 troops. During March 1944 before DDT was used, there were 19 primary malaria cases, an attack rate of 5.5 cases per 1000 troops per annum. During November and December of 1944 no primary infections were recorded for the base. A year earlier, in December 1943, there were 41 primary cases. This reduction in the incidence of malaria must be attributed, in part, to the use of DDT.

When the first village treatment was completed in early July, further reduction in malaria infections seemed unlikely because of the high *A. farauti* population beyond the controlled area. Yet the number of new infections steadily decreased. It is the opinion of the writer that this further reduction resulted chiefly from the treatment of plantation and native villages with DDT.

SUMMARY.—*Anopheles farauti*, vector of malaria and filariasis, was controlled with DDT in the advanced military base on Espiritu Santo and adjacent small islands in the New Hebrides group. *A. farauti* is more susceptible to DDT residue than is *Culex annulirostris* but more resistant than prevalent species of flies. Native huts in the uncontrolled area treated with 5 per cent DDT in kerosene at the rate of 1 gallon per 1000 square feet were free of *A. farauti* adults for 3 months. This treatment, which was applied to all plantation buildings and native huts in and near the controlled area, was undoubtedly the most valuable use of DDT in reducing malaria infections.

Breeding sites within and for at least 1 mile beyond camps were sprayed weekly with a 5 per cent solution of DDT in No. 2 diesel oil at the rate of about 2 quarts per acre. Weekly spraying was necessary because of the continuous formation of new water pools.

During December 1943 before the use of DDT, 41 primary malaria infections of military troops were recorded but during November and December 1944 no new infections were reported. This reduction in the incidence of malaria in the military troops must be attributed, in part, to the use of DDT.—7-1-47.

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# The Olfactory Responses of Female Mosquitoes[1]

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Although it has long been taken for granted that mosquitoes are attracted by animal odor, the proof of this has never been conclusive. When the attraction of mosquitoes to host odor is studied in situ, an interpretation of their reactions is often complicated by a strong response to body heat. It has been known for years that females of many species of mosquitoes will be attracted to a source of heat (Howlett 1910). Females of the two species used in this study will be attracted to any inanimate object (such as a bottle of warm water) when the temperature of the object is somewhat warmer than that of the surrounding air.

Workers in the past have been singularly unsuccessful in demonstrating the attractiveness of human body secretions and excretions to mosquitoes (Rudolfs 1922; Crumb 1922). It is thought that the lack of success might have been the result of rather crude methods which were used to present the material to the insects. However, recent investigations by Haddow (1942) suggest that human odor may be a mosquito attractant. He placed 5 washed and 5 unwashed native children in similar huts. All clothing and personal belongings were removed, and the boys slept naked in clean blankets. Records of the numbers of mosquitoes caught both days and nights indicate that the unwashed children were more attractive to *Anopheles gambiae*, *Anopheles funestus*, and *Anopheles pharoensis*. Haddow also placed the dirty clothing of 10 natives alternately on successive nights in 1 of 2 empty huts. Records of the numbers of mosquitoes caught suggest that females of *A. gambiae* and *A. funestus* were attracted by the clothing.

Since the problem of determining whether host odors are attractive to mosquitoes involves their responses to olfactory stimuli, the use of an insect olfactometer was indicated. In this type of apparatus odors may be presented to the insects under controlled conditions in such a way that the attraction or repellency of the odor is evident from the reactions of the insects. It is practically impossible to investigate the responses of insects to a single stimulus, such as host odor, without at the same time introducing other factors which may influence the reactions of the insects. A suitably designed olfactometer permits close regulation of some of these factors such as temperature, humidity, light, sound, air velocity, and contaminating odors. As a result the effects of any additional stimuli on the responses of the insects may be divorced from the action of the odor under investigation.

Some of the modern types of olfactometers use as a measure of response to an attractive odor stimulus the comparative numbers of insects clustering before 2 adjacent streams of air (Hoskins *et al.* 1934; Wieting *et al.* 1939). One air stream carries the odor to be tested while the other is an odorless control. The mosquitoes which were used in this work commonly responded to an attractive stimulus by probing toward the source of the stimulus with their proboscides. This type of response may be observed when the breath is directed against the side of a cage containing mosquitoes, or when the hand is held close to the side of the cage. In the present work the criteria of a response to an attractive odor were both a clustering of mosquitoes before the odor bearing air stream and the probing response.

MOSQUITOES FOR TESTING.—The female mosquitoes used in this work were reared from eggs obtained from laboratory stock colonies. These colonies were about 2 years old at the start of this work. Methods of rearing *Anopheles quadrimaculatus* Say were those developed by Peffly *et al.* (1946). Modifications of some of the common rearing techniques were used to supply *Aëdes aegypti* (L.).

Adult mosquitoes of known age were kept in small screen wire and cloth covered cages until tested. In these cages the sexes were mixed; females for testing were removed at random from a cage a few minutes before testing, by means of an aspirator. A different group of 50 non-blood-fed female mosquitoes was used for each test. Differences in the state of

[1] The work described in this paper was done under a contract between the Office of the Quartermaster General and The Ohio State University Research Foundation.

nutrition between individual mosquitoes were unavoidable. It is felt that these differences were minimized by random selection of mosquitoes for testing. From emergence until a few minutes before testing, water and a 5 per cent honey solution were available to the mosquitoes at all times in pads of absorbent cotton.

Within practical limits mosquitoes of nearly the same age were used in the different tests. Females of *Aëdes aegypti* were between 1 and 2 weeks old at the time of testing, and females of *Anopheles quadrimaculatus* were about 1 week old. Variations in ages within these limits did not appear to affect the responses of the mosquitoes when tested.

The small cages of known-age mosquitoes were kept under fairly uniform climatic conditions. However, the humidity of the laboratory was generally lower than that to which the mosquitoes were exposed during tests. During the day the cages of mosquitoes were exposed to bright artificial lights.

THE OLFACTOMETER.—The olfactometer shown in figure 1 is a modification of the one developed by Hoskins & Craig (1934) and by Wieting & Hoskins (1939). It utilized two similar streams of air, either of which could carry an odor while the other served as a control, together with suitable devices for regulating the rate of air flow, the temperature, and the humidity of the air streams.

Compressed air from a single source was split into two air streams at the Y shown in figure 1. Each stream passed through a calibrated flowmeter (Benton 1919). Clamps on the rubber tubing between the Y and the flowmeters permitted accurate control of the rates of air flow. Each air stream was passed through a celluloid cylinder 4 inches in diameter and 14 inches long. A man's arm could be inserted into either of these cylinders for the pur-

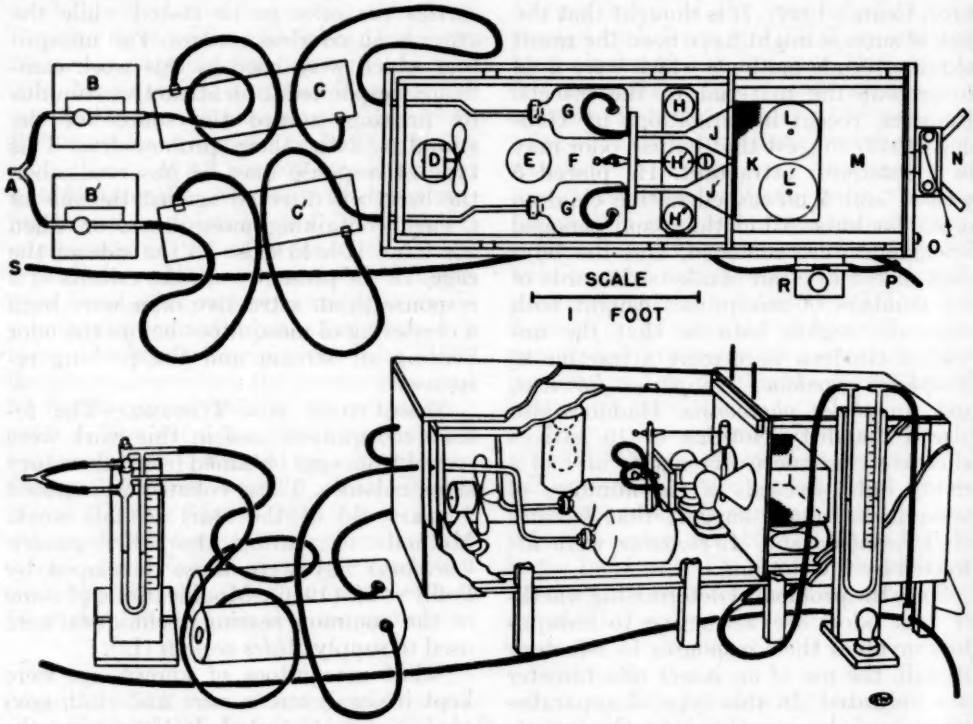


FIG. 1.—The olfactometer that was used to study the attraction of female mosquitoes to human odor. Explanation of the letters on the plan drawing: A—glass "Y" connected to compressed air line; B, B'—air line flowmeters; C, C'—right and left celluloid cylinders; D—electric fan; E—60 watt mazda lamp heating element in metal can shield; F—constant temperature cabinet; G, G'—humidifying bottles; H, H', H''—25 watt mazda lamps, photographic light source; I—mercury thermoregulator; J, J'—white plastic funnels, influent ports; K—wire screen test cage; L, L'—exhaust ports; M—reaction box; N—recording camera; O—camera cable release and switch for 25 watt lamps P—tube for operating exhaust system; R—exhaust flowmeter; S—compressed air line connection for tube.

pose of imparting human odor to the test air stream. Each cylinder was connected into its air conduit by means of rubber tubing to provide flexibility in the apparatus. This permitted the man who supplied the arm odor to regulate the rates of air flow and also to record data. A piece of latex rubber dental dam was clamped over the open end of each cylinder. A small hole in the center of the rubber end of one cylinder allowed the arm to be inserted into the test air stream. The rubber stretched around the arm, and made a tight seal near the elbow.

Both air streams were passed through a constant temperature cabinet to avoid variations in the temperatures of the air streams. The cabinet was of double wall construction, being built of half-inch insulating board with a 0.75 inch air space between the outer and inner boxes. The heating element was a 60 watt light bulb; the intermittent flashing of this bulb was masked by a metal can shield. The temperature of the box was controlled by a mercury thermo-regulator and an electromagnetic relay.

Moisture was added to each stream by passing the air over distilled water in a humidifying bottle in the constant temperature cabinet. Each air stream was discharged into a dark reaction box through 2 translucent funnels or ports 4 inches in diameter. Waste air was drawn from the reaction box through 2 exhaust ports, each 4 inches in diameter. Close control of the exhaust rate was maintained by the use of a flowmeter in the exhaust air line. Suction was provided across this flowmeter to the exhaust ports by means of a tube which was operated by compressed air.

A test cage measuring 5 by 8 by 6 inches was made of wire screen and glass. The 5 by 8 inch wire screen side of the cage was placed against the rims of the influent ports in the reaction box during a test. The single glass side was toward the recording camera. The bottom of the cage was raised on a wire frame above the floor of the reaction box. The glass side of the cage was above the rear edges of the rims of the exhaust ports.

Opposite the influent ports, centered in the end of the reaction box, was an observation port. Records of the distribution of mosquitoes on the areas of the test cage adjacent to the funnel rims were made photographically. A photographic method of recording data was chosen from necessity because the movement of mosquitoes to and away from the areas of the test cage before the ports was too rapid to permit accurate counting. In addition it was possible in this way to make simultaneous records of the numbers and the distribution of the mosquitoes before each port. Photographs were taken at 1 minute intervals for a 10 minute test period.

Thirty-five-millimeter cameras were used throughout this work to record all data. A supplementary lens permitted focusing on the side of the test cage from a distance of 13 inches. A lens opening of f.3.5 and a shutter speed of 0.05 second were used with film which had a Weston rating of 50.

Three 25 watt lamps supplied the light for photographing the distribution of mosquitoes before the ports. The lamps were located symmetrically behind the translucent funnels in the constant temperature box. This light source silhouetted the mosquitoes against the side of the cage (Fig. 2). This method of illumination was chosen, in preference to a conventional light source from the vicinity of the camera, to avoid establishing a counter-attractant of heat which would operate from a direction opposite the funnel openings. The lights were controlled by a push button switch on the end of the reaction box near the camera cable release; both lights and camera could be operated

FIG. 2.—Responses of females of *Aëdes aegypti* (L.) to the odor of a man's arm in the olfactometer. The photograph was taken at the end of the first minute after the start of test B 42. The test air stream which contained the odor was on the right. The bulbs of the air stream thermometers project down into the centers of both the test and control ports.

simultaneously with one hand. The influent ports were illuminated for periods of less than 0.5 second for each photograph. During the intervals between photographs the mosquitoes were in darkness.

Counts of mosquito distribution before each port were made from the developed film. Only those mosquitoes that were in focus on the screen over the area outlined by each funnel rim were counted. Sums of the numbers of mosquitoes before each port were obtained for each test from the 10 negatives that were the record of the test. It was realized that still photographs would not indicate whether the mosquitoes were merely resting on the screen before each port, or whether they were actively probing the area. Actual observations of tests showed that the mosquitoes did respond to the stimuli by probing through the screen side of the cage into the air streams. As they probed, the mosquitoes rapidly shifted position over the area. It was concluded that data taken photographically in these tests were as valid as could be obtained visually, and such data were certainly more accurate than could have been obtained otherwise.

Comparable values which indicate the attractiveness or repellency of the test odor were computed as a percentage from the total responses to each air stream for a series of tests (Hoskins *et al.* 1934). The per cent response, $P$, to the test air stream was computed from the formula:

$$100\left(\frac{T}{T+C}\right)=P$$

where $T$ equals the number of responses to the test air stream, and $C$ equals the number of responses to the control air stream. A series of blank (odorless) tests will show close to a 50-50 distribution of mosquitoes before the 2 ports. For such a distribution the response to either air stream, computed in the manner stated, will be 50 per cent. In a series of tests in which odor has been introduced into one air stream, an attraction of the insects to the odor will be shown by a value greater than 50 per cent; if the odor is repellent, a value less than 50 per cent will be obtained.

TESTING TECHNIQUE.—The tests were all conducted in the same manner. About 10 minutes before the start of a test a group of 50 female mosquitoes was transferred to the test cage. If arm odor was to be the test attractant the arm was slipped into the cylinder in the test air line 5 minutes before the start of the test. The temperature of the interior of the reaction box was measured to determine the gradient between the rear of the test cage and the air streams. A paper bearing the test number and the date was placed in a small window in the end of the reaction box between the influent ports. After the test cage had been placed in the reaction box, the box cover was quickly replaced; two air stream thermometers were inserted through small holes in the cover so that the bulbs were centered in the influent air streams between the ports and the test cage (Fig. 2).

A watch with a sweep second hand was observed so that photographs could be made at intervals of 1 minute. After exposing the film at the end of each minute, a record was made of the air stream temperatures. Then, during the intervals between photographs, a routine check was made of the flowmeters. If necessary, the regulating valves were adjusted to maintain constant rates of flow.

Half of each series of tests was run with the odor in the left hand air stream. At the completion of those tests the apparatus was disassembled and washed before the other half series was run with the odor in the right hand stream.

During the arm odor tests with *Aëdes aegypti*, 6 minutes elapsed after the placing of the test cage in the reaction box and the taking of the first photograph. Arm odor tests with *Anopheles quadrimaculatus* and all subsequent tests with *Aëdes aegypti* were run without a 5 minute waiting period. In these latter tests the first photograph was made at the end of the first minute after placing the cage in the reaction box. Adequate response to the odor was obtained within 1 minute of the start of the test.

TEST CONDITIONS.—Before running tests in which an odor or test condition was imparted to an air stream, a series of routine blank tests was run. The responses of the mosquitoes to these odorless tests indicated whether there was a biased response to either air stream. If a biased response of any magnitude was obtained in blank tests, the apparatus was recleaned and retested before proceeding

with tests containing odor. As a means of cancelling the effect of any slightly biased response of unknown origin, the tests were run with the odor in the right hand air stream for half of each series of tests, and with the odor in the left hand air stream for the other half series.

The temperature of both air streams for nearly all of the tests was maintained at $34 \pm 0.6°$ C. at the points of entrance of the air into the test cage. A constant check on this temperature was obtained by placing thermometers, with their bulbs centered in the influent air streams, between the ports and the cage. A temperature of 34° C. was selected because it closely approximates the skin temperature of the human arm. The presence of the warm arm in the test air line at a distance of 6 feet from the test port did not influence the temperature of the test air stream, measured at the test port, at any temperature that was selected for any group of tests.

A temperature gradient existed during these tests from the rear of the test cage to the screen side of the cage that was in contact with the influent ports. The rear of the cage was from 4 to 7° C. cooler than the air streams. Although a temperature gradient also existed from the center of each port toward the periphery of the funnel with the highest temperature at the center, neither species of mosquito appeared to orient to any particular temperature zone (Fig. 2).

The humidities of both test and control air streams were maintained in the range 70 to 85 per cent relative humidity. When the arm was inserted into the cylinder in the test air stream, distilled water was placed in the other cylinder to provide moisture to match that given off from the arm. Additional moisture was added to each air stream in the humidifying bottles in the constant temperature cabinet. It was found to be necessary to humidify the air streams since the relatively dry air from the compressed air line appeared to repel the mosquitoes. After moisture was added to the air streams, the mosquitoes would fly to the side of the cage before the ports. Because of variations in the amount of moisture given off by the arm from test to test, it was impossible to maintain the two air streams at the same humidity at all times. However, these humidity differences were small. Differences of 5 to 10 per cent relative humidity between the air streams did not influence the responses of the mosquitoes. This was determined by running several series of odorless tests with a humidity difference as the only variable between the air streams.

All tests were run in darkness to eliminate a light stimulus and to avoid a biased orientation of the insects under unequal illumination of the influent funnels. There was a total illumination of less than 5 seconds during the 10 minute test period. The brief flashes of light behind the funnels would cause the mosquitoes to fly away from the ports. In the periods of darkness between successive photographs those mosquitoes that were attracted to the air streams would fly to the side of the cage before the ports.

The rate of air flow of each air stream was either 100 or 150 liters per hour. Both rates were satisfactory as long as the exhaust rate was 50 per cent greater than the combined inflow of both test and control air streams. Because of unavoidable variations in both the quality and the intensity of the arm odor between groups of tests, the combinations of air flow and exhaust rates may not have been the best to obtain a maximum response to the arm odor.

Extraneous odors were excluded from both air streams in so far as was practicable. Rubber is known to impart an odor to the air streams (Dethier 1941); it was not practical to eliminate this material since it was desired to retain flexibility in the apparatus by using rubber tubing in parts of the air conduits. However, rubber items were matched in the air streams so that similar odors would be imparted to each. The possible effects of certain odors are discussed in connection with the test data.

TESTS WITH ARM ODOR.—Before attempting to isolate the specific components of human odor that might be attractive to mosquitoes, tests were run to determine whether human odor in its entirety would attract mosquitoes. The arm was chosen as the source of the odor because it could be sealed in the test air stream more easily than any other part of the body. Tests run under the above conditions indicated that non-blood-fed females of *Aëdes aegypti* and of *Anopheles quadrimaculatus* are attracted to the odor of the

Table 1.—Responses of females of *Aëdes aegypti* (L.) in individual tests in the olfactometer.

| Test No. | | Number of Mosquitoes per Area Before Each Port at End of Minute | | | | | | | | | | Total Responses |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| A 54 | Right Hand Port | 3 | 8 | 6 | 4 | 6 | 3 | 3 | 4 | 2 | 6 | 45 |
| (Blank) | Left Hand Port | 5 | 2 | 3 | 4 | 1 | 5 | 5 | 4 | 9 | 8 | 46 |
| B 42 | Test Port | 15 | 12 | 6 | 14 | 6 | 7 | 10 | 6 | 10 | 9 | 95 |
| (Arm odor) | Control Port | 3 | 0 | 2 | 1 | 3 | 2 | 1 | 3 | 1 | 2 | 18 |

Temperature of air streams: 34 ± 0.6° C.
Rate of air flow: 100 liters per hour.
Rate of exhaust: 300 liters per hour.

human arm and hand. Table 1 shows the responses of females of *Aëdes aegypti* in individual tests in the olfactometer. Although these are representative tests, considerable variation in response was recorded from test to test. However, variations in response between the individual tests tended to smooth out when the total responses for all tests in a series were added.

Table 2 shows the responses of females of both species of mosquitoes to arm odor under various conditions. It will be noted that under conditions in which the air stream temperature was 34° C. and the rate of air exhaust was 50 per cent greater than the combined inflow of both air streams, strong responses to arm odor were obtained. This is evidenced by values of over 70 per cent attraction to arm odor. However, at higher or lower temperatures, or at reduced exhaust rates the magnitude of the per cent attraction to the arm odor was considerably reduced. It is realized that variations in arm odor between the groups of tests may have affected the responses of *Aëdes aegypti*, and that as a result the low per cent attraction may not be entirely attributable to planned variations in the experimental conditions.

The possibility that the odor of the rubber dental dam or the celluloid in the cylinder, which were both warmed by the arm, might have been attractive to the mosquitoes was eliminated in later tests. For these tests the end of the cylinder in the test air line, including both rubber dental dam and celluloid, was warmed to 37° C. by a 15 watt light bulb. The unwarmed end of the other cylinder served as a control.

The action of the pulse in the arm as an attractive stimulus to females of *Aëdes aegypti* was eliminated by covering the arm with an elbow length surgical rubber glove. The mate to this glove was placed in the control air stream. The presence of a pulsation in the air stream was indicated by a regular pulsation of the indicator fluid in the test air line flowmeter. The rate of pulsation corresponded with the pulse rate at the wrist of the test arm, *viz.* 85 beats per minute. By covering the arm with the glove the pulsation was still

Table 2.—Responses of female mosquitoes in the olfactometer to odor from a man's arm and hand.

| Test Conditions | No. of Tests | Total Responses to Air Streams | | Per Cent Attraction to Odor |
|---|---|---|---|---|
| | | Test | Control | |
| Species: *Aëdes aegypti* (L.) | | | | |
| Air Stream Temp.: 34° C. Air Flow: 100 L./Hour Exhaust: 300 L./Hour | 40 | 2498 | 947 | 73 |
| Air Stream Temp.: 24–26° C. Air Flow: 100 L./Hour Exhaust: 300 L./Hour | 10 | 195 | 180 | 52 |
| Air Stream Temp.: 36.5° C. Air Flow: 100 L./Hour Exhaust: 300 L./Hour | 10 | 463 | 369 | 56 |
| Air Stream Temp.: 34° C. Air Flow: 100 L./Hour Exhaust: 300 L./Hour | 10 | 546 | 353 | 61 |
| Air Stream Temp.: 34° C. Air Flow: 100 L./Hour Exhaust: 200 L./Hour | 10 | 534 | 380 | 58 |
| Air Stream Temp.: 34° C. Air Flow: 100 L./Hour Exhaust: 250 L./Hour | 10 | 420 | 369 | 53 |
| Species: *Anopheles quadrimaculatus* Say | | | | |
| Air Stream Temp.: 34° C. Air Flow: 100 L./Hour Exhaust: 300 L./Hour | 10 | 418 | 167 | 72 |
| Air Stream Temp.: 34° C. Air Flow: 150 L./Hour Exhaust: 450 L./Hour | 10 | 502 | 100 | 83 |

imparted to the test air stream, as indicated by the flowmeter, but the arm odor was excluded. In the absence of odor the mosquitoes were not attracted to the test air stream by the pulsation.

Table 3 shows the responses of females of both species of mosquitoes to various experimental conditions from which the arm odor was excluded. It was considered possible that these conditions might have attracted mosquitoes to the test air stream during the arm odor tests. Yet the per cent attraction to the test air stream under each condition was not indicative of attraction, being in every example very close to 50 per cent. One series of tests with females of *Anopheles quadrimaculatus* indicated a slight preference for the air stream with the higher humidity. However, a second series that was run under very similar conditions showed that there was no attraction of this species to the higher humidity.

It was concluded from these arm odor tests that arm odor was the only attractive stimulus that elicited a strong response from both species of mosquitoes. All other factors were eliminated as attractive stimuli, or were balanced in test and control air streams.

There is an indication that a relationship exists between the attractiveness of human odor and the temperature at which it is presented to *Aëdes aegypti*. However, this can be investigated satisfactorily only when some specific attractant has been isolated in pure form from the human odor complex. As it is, variations in the odor obtained directly from the body make it impossible to get comparable data under a variety of conditions.

CARBON DIOXIDE AS A MOSQUITO ATTRACTANT.—In view of the many statements encountered in the literature that carbon dioxide is a mosquito attractant, this compound was selected from all the possible constituents of human odor for testing in the olfactometer. In addition to the carbon dioxide eliminated through the lungs, small amounts of the compound are lost through the skin. The amount of carbon dioxide that passes through the entire skin surface of man is ordinarily from 7.5 to 9 grams for a 24 hour period (Hammarsten *et al.* 1914). Since this is only about 1.5 per cent of the quantity excreted through the lungs, it might be expected that the carbon dioxide from the lungs would be the more important stimulus if the gas is a mosquito attractant. However, in the previous tests in the olfactometer only carbon dioxide excreted through the skin could have affected the responses of the mosquitoes tested.

**Table 3.—Responses of female mosquitoes in the olfactometer to various experimental conditions.**

| Test Conditions | No. of Tests | Total Responses to Air Streams: Test | Total Responses to Air Streams: Control | Per Cent Attraction to Test Conditions |
|---|---|---|---|---|
| Species: *Aëdes aegypti* (L.) | | | | |
| Relative Humidity of Air Streams:* Test: 74–89% Control: 60–78% | 10 | 300 | 293 | 51 |
| Relative Humidity of Air Streams: Test: 86% Control: 78–80% | 10 | 393 | 377 | 51 |
| Pulsation in Test Air Stream;* Arm Odor Excluded by Rubber Glove | 7 | 327 | 353 | 48 |
| Rubber Dam and End of Celluloid Cylinder in Test Air Stream Warmed to 37° C. | 10 | 363 | 373 | 49 |
| Species: *Anopheles quadrimaculatus* Say | | | | |
| Relative Humidity of Air Streams: Test: 86% Control: 78–80% | 10 | 260 | 213 | 55 |
| Relative Humidity of Air Streams: Test: 85–88% Control: 80–81% | 10 | 215 | 212 | 50 |
| Rubber Dam and End of Celluloid Cylinder in Test Air Stream Warmed to 37° C. | 10 | 203 | 176 | 53 |

Temperature of air streams: 34 ± 0.6° C.
Rate of air flow: 150 liters per hour
Rate of exhaust: 450 liters per hour
* These tests only:
Rate of air flow: 100 liters per hour
Rate of exhaust: 300 liters per hour

Although Rudolfs (1922) assumed that "the large quantities of $CO_2$ produced by breathing may be the initial attractive agent for the mosquitoes," nowhere does he describe an attractive response of the mosquitoes tested that can be attributed directly to the action of carbon dioxide. In fact he refers to the compound as an activating agent which made the mosquitoes restless. Crumb (1922) observed that an air stream that contained various amounts of carbon dioxide was no more attractive to *Culex pipiens* than undiluted air. Streams of both air alone and carbon dioxide and air were passed through warm water, and then directed against the side of a cage containing mosquitoes.

Headlee (1934, 1941) reported that with the use of carbon dioxide, both as a gas and as dry ice, the total mosquito catch in a New Jersey type electric light gauge was materially increased. He attributed the increased catch to the action of carbon dioxide as a mosquito attractant as have later workers (Huffacker *et al.* 1943). However, the possibility that the carbon dioxide employed with these traps might have acted in some manner other than as an attractant has not been excluded. This point is raised because carbon dioxide was found to be nonattractive to mosquitoes tested in the olfactometer.

TESTS WITH CARBON DIOXIDE.—Changes were made in the olfactometer before tests with carbon dioxide were run. Both celluloid cylinders were removed from the air conduits, and the air line flowmeters were connected directly to the humidifying bottles in the constant temperature cabinet. A mixing bottle was installed in each air line between each humidifying bottle and the stem of the corresponding influent funnel. The mixing bottle prevents the more rapidly moving air stream from blocking the flow of the more slowly moving air stream (Dethier 1941). A carbon dioxide line was connected into each mixing bottle through a three-way valve. By means of this valve carbon dioxide could be added to either air stream for each half series of tests. A humidifying bottle similar to the ones in the air lines was installed in the carbon dioxide line in the constant temperature box. Another flowmeter was installed to handle carbon dioxide. Two flowmeters of widely different capacities were used for carbon dioxide depending on the volume of gas that was to be added to the test air stream.

Commercial carbon dioxide from a cylinder of the compressed gas was used for all tests. Three concentrations of carbon dioxide in air were used to survey the responses of female mosquitoes to this compound. Concentrations of 1, 10, and 50 per cent carbon dioxide in air (by volume) were obtained by adjustment of the rates of flow of air through one air line flowmeter and carbon dioxide through the carbon dioxide flowmeter so that the resulting mixture would be of the desired concentration. The control stream was air alone; its rate of flow equalled the combined rates of flow of air and carbon dioxide in the test air stream. In all tests the percentage of carbon dioxide in the test air stream was in addition to that normally present in the atmosphere.

Before testing the responses of mosquitoes to various concentrations of carbon dioxide, blank tests were run to determine whether there was a biased response to either air stream. In these tests air alone was passed through all three flowmeters. The test air stream was air which had passed through two flowmeters (the test air line flowmeter and the carbon dioxide flowmeter) with a combined rate of flow of 150 liters per hour. The control stream was air which had passed through the other air line flowmeter at a rate of 150 liters per hour. An exhaust rate of 450 liters per hour was used for all tests. During these blank tests the mosquitoes responded in nearly equal numbers to both the test and the control air streams.

When running tests with carbon dioxide, the gas was allowed to flow freely through the conduit until all air had been pushed out before the first test of the day was run. During the remainder of the day the gas and air lines were kept flowing to maintain the desired concentration of gas In the 1 per cent, 50 per cent, and the second series of the 10 per cent carbon dioxide tests, the air for both test and control air streams was passed through distilled water between the air source and the air line flowmeters. By this means the humidities of the air streams were raised into the range 70 to 85 per cent relative humidity. However, the first series of 10 per cent carbon dioxide tests was run before the additional humidifying bottle had been placed in the air line. The humidities of both air streams during that series of tests were in the range 50 to 60 per cent relative humidity.

Table 4 shows the responses of female mosquitoes to different concentrations of carbon dioxide in the olfactometer. The range of values of per cent attraction to the various concentrations of carbon dioxide was from 42 to 59 per cent. These values lie relatively close to 50 per cent, and when compared to the strong attraction of over 70 per cent in the arm odor tests, they do not indicate that carbon dioxide is a mosquito attractant. Some of the figures require further comment. The value 59 per cent attraction to 50 per cent carbon dioxide that was ob-

tained with *Aëdes aegypti* appears to indicate a slight attraction of this species to the gas. However, this value is thought to be artificially high because of what might have been an anesthetic action of carbon dioxide.

It is known that carbon dioxide will anesthetize mosquitoes as well as other insects. The mixture of carbon dioxide and air in the olfactometer (further diluted by additional air which was drawn into the reaction box by the exhaust system) was not of sufficiently high concentration to anesthetize the mosquitoes completely, but it did slow down their activity. Rudolfs (1922) observed a similar slowing down of mosquito activity in unspecified concentrations of carbon dioxide and air.

Visual observations were made of the actions of mosquitoes in the olfactometer while 50 per cent carbon dioxide was flowing to the test port. It was observed that the activity of both species appeared to be reduced in the presence of this high concentration of the gas. In addition there was a tendency for mosquitoes which had gained a particular position on the side of the test cage to retain that position throughout the test. It was also noted that individuals of *Aëdes aegypti* which came to rest on the screen before the test port tended to remain in that position even after the lights behind the funnels had been flashed on. Heretofore it had been observed that mosquitoes would fly away from the bright light a fraction of a second after the light had been flashed on. In the 50 per cent carbon dioxide tests females of *Aëdes aegypti* which alighted on the side of the cage at the test area exhibited none of the reactions usually associated with attraction. The mosquitoes did not fly rapidly to and away from the test area, nor did they probe into the air stream. The hypothesis is advanced that those mosquitoes which landed on the screen close to the test air stream of 50 per cent carbon dioxide were retained in that position not by the attraction of carbon dioxide but by the action of the gas as an anesthetic.

Considering the lack of effect that 10 per cent carbon dioxide had on the reactions of females of *Aëdes aegypti*, it is curious that 42 per cent response to 1 per cent carbon dioxide, an indication of repellency, was obtained. This result is

**Table 4.—Responses of female mosquitoes in the olfactometer to various concentrations of carbon dioxide.**

| Concentration of Carbon Dioxide | No. of Tests | Total Responses to Air Streams | | Per Cent Attraction to $CO_2$ |
|---|---|---|---|---|
| | | Test | Control | |
| Species: *Aëdes aegypti* (L.) | | | | |
| 1% $CO_2$ in Air | 10 | 442 | 599 | 42 |
| 10% $CO_2$ in Air (50–60% R.H.) | 10 | 294 | 304 | 49 |
| 10% $CO_2$ in Air | 10 | 397 | 402 | 50 |
| 50% $CO_2$ in Air | 10 | 390 | 270 | 59 |
| Species: *Anopheles quadrimaculatus* Say | | | | |
| 1% $CO_2$ in Air | 10 | 507 | 484 | 51 |
| 10% $CO_2$ in Air (50–60% R.H.) | 10 | 212 | 157 | 57 |
| 10% $CO_2$ in Air | 10 | 258 | 262 | 50 |
| 50% $CO_2$ in Air | 10 | 122 | 160 | 43 |

Temperature of air streams: 34 ± 0.6° C.
Rate of air flow: 150 liters per hour.
Rate of exhaust: 450 liters per hour.

valid and there is no good reason for not accepting it. On the other hand the value of 43 per cent response of females of *Anopheles quadrimaculatus* to 50 per cent carbon dioxide is of doubtful validity since so few insects responded during these tests. Many of the mosquitoes that did respond in this series of tests could be seen occupying the same positions on the screen before the ports in several successive photographs of a particular test. This unchanging distribution had occurred only rarely in previous tests in which the arrangement of mosquitoes changed markedly from minute to minute.

The enhanced responses of both species in the presence of 1 per cent carbon dioxide seems to be an indication that carbon dioxide is activating to mosquitoes at certain concentrations. The larger numbers of responses during the two series of tests at this concentration are undoubtedly the result of greater insect activity. This conclusion corroborates observations by Rudolfs (1922) that carbon dioxide activates mosquitoes.

It was concluded that carbon dioxide in the concentrations tested was not an attractant for females of *Aëdes aegypti* or *Anopheles quadrimaculatus* under the conditions of these tests. It was also concluded that carbon dioxide that was excreted through the skin was not the chemical that attracted these mosquitoes to the test air stream during the arm odor tests.

Other tests which have been run in the olfactometer, but which are not reported in detail, indicate certain tendencies. Large series of tests were not run so definite conclusions cannot be drawn. Blood-fed females of *Aëdes aegypti* are apparently not attracted by arm odor under conditions that elicit a strong response to the odor from non-blood-fed females; the mosquitoes in these tests were fed on human blood 1 to 3 days before testing. The males of *Aëdes aegypti* are apparently unattracted by human odor. Withholding food (honey solution) but not water from females of both species of mosquitoes for periods up to 48 hours before testing did not increase the responses of the mosquitoes to warm, moist air streams.

SUMMARY.—A modification of the Hoskins insect olfactometer which was used successfully with mosquitoes is described. Data are presented which indicate that females of *Aëdes aegypti* (L.) and *Anopheles quadrimaculatus* Say are attracted by the odor of the human arm when the odor is presented at a temperature of 34° C. and in a humidity range of 70 to 85 per cent relative humidity.

Data are presented which indicate that carbon dioxide in concentrations of 1, 10, or 50 per cent in air is not an attractant for females of *Aëdes aegypti* (L.) or *Anopheles quadrimaculatus* Say when tested in the olfactometer.

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# Tests with New Insecticides for Control of the Sugarcane Borer

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Several new insecticides have been tested on field plots of sugarcane and sorghum at Houma, La., in search of a more effective and less expensive material than cryolite for use in the control of the sugarcane borer, *Diatraea saccharalis* (F.). Cryolite is now widely used for this purpose in Louisiana, but in addition to being rather expensive it sometimes causes heavy increases in yellow sugarcane aphid, *Sipha flava* (Forbes) infestations or some foliage injury.

Methods.—Each treatment was replicated five to 10 times. Some of the tests were conducted in the spring against first-generation borers, and some were conducted against third- and fourth-generation borers in summer-planted cane in September, when it is similar in size and growth to cane at time of first-generation injury. Twentieth-acre plots were used for these tests, and in most cases the insecticides were applied four times at weekly intervals beginning with the hatching of the first eggs. Where a dust was used, each application was at the rate of approximately 8 pounds per acre. The number of live borers surviving treatment was determined by dissecting all dead cane shoots, called dead hearts, in equal lengths of row on each plot, leaving buffer areas 6 feet wide on each side and 3 feet wide on each end, since the dead hearts contain over 95 per cent of all borers surviving in the young growth present in the spring on established stands, or in September on new plantings made the preceding summer.

The tests against second- or third-generation borers in tall cane were conducted on thirtieth-acre plots. In most cases each insecticide was applied four times at weekly intervals, beginning with the hatching of the first eggs. Each application of all dusts tested was at the rate of 10 pounds per acre. Degree of control was determined by counting the joints of cane bored and those not bored (internodes) in 50 or 100 stalks per plot.

DDT.—As shown in table 1, in 1943 and 1944 a dust containing 10 per cent of DDT in pyrophyllite was much less effective than undiluted synthetic cryolite (90 per cent fluoaluminate) against first-generation borers. When this dust was tested against the second generation in tall cane and against the third and fourth generations in summer-planted cane, it was much less effective than cryolite, and in two of the tests there was an increase in borer infestation over that present in the untreated plots. In 1944 a spray formulation containing 20 pounds of 10 per cent DDT-pyrophyllite and 7.5 ounces of sticker-spreader to 100 gallons of water, applied at the rate of 50 gallons per acre, was also much less effective than cryolite against the third and fourth generations.

In 1945 the number of borers increased after various DDT spray formulations had been applied to summer-planted cane. These formulations (quantities in 6 quarts of spray) gave the following increases when applied at the rate of 2½ gallons per acre:

| | Per Cent |
|---|---|
| DDT 24 ounces, xylene 3 pints, *Igepal CA*[2] 30 cc. in water | 57 |
| DDT 12 ounces in kerosene | 63 |
| DDT 24 ounces, *Velsicol AR-50*[3] 3 pints in fuel oil | 73 |
| DDT 24 ounces, xylene 3 pints in fuel oil | 76 |

In the same experiment undiluted cryolite, dusted at the rate of 10 pounds per acre, gave 61 per cent reduction.

There was also nearly always a heavy increase in numbers of yellow sugarcane aphids following treatment with DDT. In the 1943 experiment six times as many leaves were infested with this aphid in the plots treated with DDT as in the untreated check plots, and over twice as many as in the plots treated with synthetic cryolite.

A dust containing 10 per cent of the methoxy analog of DDT (1-trichloro-2,

[1] W. E. Haley collaborated in the project here reported.

[2] Condensation product of ethylene oxide and an alkylated cresol.

[3] Chiefly mono- and di-methylnaphthalenes.

2-bis (*p*-methoxyphenyl) ethane) was included among the insecticides tested on summer-planted cane in 1946. This gave only 14 per cent control of the borer, whereas undiluted cryolite gave 72 per cent control in the same test. There were also noticeably greater numbers of yellow sugarcane aphids in the plots treated with the methoxy analog of DDT than in the check plots.

The results of the experiments reported on in this paper certainly indicate that DDT and its methoxy analog are of no value for the control of the sugarcane borer.

*Ryania.*—Experiments with *Ryania* dust are summarized in table 2. In the 1946 experiments against first-generation borers a dust containing 50 per cent of

**Table 1.—Per cent control of borers in sugarcane treated with DDT and with synthetic cryolite. Houma, La., 1943, 1944.**

| Generation | 10 Per Cent DDT | Undiluted Synthetic Cryolite |
|---|---|---|
| 1943: | | |
| First | 74 | 97 |
| 1944: | | |
| First | 11 | 85 |
| | 3½ | 81 |
| Second (in tall cane) | 18[1] | 61 |
| Third and fourth (in young summer-planted cane) | 172[1] | 88 |
| | 9[1] | 95 |

[1] Increase.

*Ryania* was applied three times at 10-day intervals. This dust gave about the same borer control as did cryolite applied the usual four times at 7-day intervals. In the same experiments a dust containing 25 per cent of *Ryania* gave about the same control as, or poorer control than, cryolite. On summer-planted cane in 1946, 50 per cent *Ryania* dust and cryolite gave about equal control. On second-generation borers in 1945 undiluted *Ryania* dust gave a much higher degree of control than did cryolite. On third-generation borers in the same year 25 per cent *Ryania* dust was apparently somewhat more effective than cryolite.

No increase in yellow sugarcane aphid populations was observed in plots treated with undiluted *Ryania* dust. In one test on second-generation borers in 1946 the aphid population was only 11 per cent greater in the plots dusted with 25 per cent *Ryania* than in the untreated plots. In the same test the aphid population was 39 per cent greater in the plots treated with cryolite than in the untreated plots. *Ryania* dust did not injure the sugarcane foliage.

Fifty per cent *Ryania* dust also gave 48 per cent control of third-generation sugarcane borers attacking sorghum and did not injure the foliage. This is of particular interest, since experiments have shown that the use of cryolite for the control of the sugarcane borer in sorghum is not practical because it injures the foliage severely.

*Benzene hexachloride.*—As shown in table 2, in 1946 benzene hexachloride dusts containing 1 and 1.5 per cent of the gamma isomer gave fully as good control of first-generation borers as did cryolite. A dust containing 2 per cent of the gamma isomer was more effective than cryolite in controlling borers in summer-planted cane in the 1945 experiment, but much less effective in the 1946 experiment. Against second-generation borers a dust containing 1.15 per cent of the gamma isomer was somewhat less effective than cryolite.

In two 10-replicate experiments the number of yellow sugarcane aphids present following the use of a dust containing 1.15 per cent of the gamma isomer to control second-generation sugarcane borers was significantly lower than the number found in plots treated with cryolite or with a dust containing 50 per cent of sodium fluosilicate. Sucrose analyses and total weights of cane were obtained in these two experiments. The plots dusted with benzene hexachloride yielded 1025 pounds more sugar per acre in one experiment and 321 pounds more in the other, than the untreated checks.

In an experiment on third-generation sugarcane borers in sorghum a dust containing 2 per cent of the gamma isomer gave a control of 27 per cent. No foliage injury to either sugarcane or sorghum was observed.

*Chlorinated Camphene.*—In 1946 a dust containing 10 per cent of a chlorinated camphene gave better control (99 per cent) than did cryolite (86–94 per cent) of first-generation borers and also of

Table 2.—Per cent control of the sugarcane borer with *Ryania*, benzene hexachloride, and cryolite. Houma, La., 1945, 1946.

| Insecticide (Per Cent of Active Ingredient) | 1945 Tests on Indicated Generations | | 1946 Tests on Indicated Generations | | | |
|---|---|---|---|---|---|---|
| | Second | Third and fourth in summer-planted cane | First | Second | Third, in tall cane | Third and fourth in summer-planted cane |
| *Ryania:* | | | | | | |
| 50 | 83[1] | 88 | 88<br>77[2] | — | — | 84 |
| 25 | — | 67 | 72<br>88 | — | 35 | — |
| Benzene hexachloride (gamma isomer): | | | | | | |
| 1.0 | — | — | 93<br>00 | — | — | — |
| 1.15 | — | — | — | 65<br>78 | — | — |
| 1.5 | — | — | 96<br>95 | — | — | — |
| 2.0 | — | 75 | — | — | — | 47 |
| Cryolite, synthetic (check) | 61 | 63 | 92<br>94<br>86 | 72<br>79 | 32 | 83<br>72 |

[1] Undiluted.
[2] Applied 3 times at 10-day intervals.

third- and fourth-generation borers in summer planted cane. A 5 per cent dust was also tested on the latter generations, but gave somewhat less control (62 per cent) than did cryolite (72 and 83 per cent).

The number of yellow sugarcane aphids present following treatment with the 10 per cent dust for second-generation borer control was significantly less than in the plots dusted with cryolite or 50 per cent sodium fluosilicate. Chlorinated camphene caused no injury to sugarcane foliage.

*Sabadilla and Chlordane.*—In 1946 poor control of the borer was obtained with both a 10 per cent dust of sabadilla and a 5 per cent dust of technical chlordane,[4] a control of 78 and 51 per cent, respectively.

CONCLUSIONS.—*Ryania*, benzene hexachloride, and a chlorinated camphene have all shown much promise as sugarcane borer insecticides, and further intensive testing of these materials is desirable to determine their practical usefulness in borer control. DDT in both dust and spray form has given decidedly unfavorable results in experimental trials against the sugarcane borer, and very poor control of the borer has been obtained with sabadilla and chlordane dusts at the strengths tested.—6-20-47.

[4] *Velsicol 1068.*

# The Effects of Feeding DDT-Treated Insects to Nestling Birds[1]

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The here reported studies were carried on from June 3 to August 6, 1946. All the nests were located within a 15 mile radius on Lake Clear Junction, New York, with the majority being centered at either Lake Clear Villa on Lake Clear, or at an abandoned State Forest Service nursery about a mile east of Lake Clear Junction.

OBJECTS OF THE STUDY.—Recent studies have shown that DDT when applied at the rate of 1 to 2 pounds per acre will not disturb the bird populations to any appreciable extent (Stewart *et al.* 1946; Hotchkiss & Pough 1946; Kendeigh 1947). However, Hotchkiss & Pough report that a single airplane application of DDT in oil at 5 pounds per acre to a forest in northeastern Pennsylvania resulted in the death of birds and a conspicuous reduction in the breeding population. Spraying of the nests, eggs and nestlings at 5 pounds DDT per acre produces no appreciable effect, as shown by Mitchell (1946). Therefore, it may be permissible to assume that any bird mortality or significent change in bird populations probably results from the birds consuming DDT contaminated food or a lack of insectivorous food in extensive areas sprayed by DDT.

Coburn & Triechler (1946) report 5-week old quail died when fed a mash diet containing 0.05 per cent or more DDT and 50 per cent died when fed DDT at a level of 0.025 per cent of the diet. During the summer of 1945, at the Patuxent Research Refuge, R. T. Mitchell fed lepidopterus larvae which had been sprayed by hand at a rate of 5 pounds DDT per acre to nestlings in the field. A tabulation of this study is given in table 1.

Of the 19 nestlings studied 8 were checks and 11 were subjects. All of the checks lived and 3 of the 11 subjects died. The cause of the death in the case of the subjects is unknown; but there is a possibility that DDT toxicity contributed to their deaths.

Since, in general, the checks were inclined to leave the nest sooner than the treated subjects it appears that the feeding of DDT treated insects has some detrimental effect upon development. The evidence from this experiment was not conclusive, and to further determine the effect of feeding DDT killed or treated insects to nestling passerine birds the present study was undertaken.

FIELD STUDY: (10 Nests).—In the field study every effort was made to permit a normal development of the nestlings under natural conditions except for the experimental feeding. The birds remained in their nests and were undisturbed but for daily weighings and feeding.

In each nest one nestling was designated as a *check* and was fed insect larvae not exposed to DDT. The remaining nestlings were treated as *subjects* and fed DDT killed or treated insect larvae.

In the first eight of the 10 nests studied, the nestlings were fed approximately 25 per cent of their body weight in food each day. The parent birds provided the additional food and all care required by the nestlings.

In handling the last two nests an effort was made to provide each nestling 50 per cent of its body weight in food each day. In these two nests there was, in addition to the *check*, fed normal insect larvae, and the *subjects*, fed DDT contaminated larvae, one nestling designated as the *field check*. The *field check* was not fed experimentally. It remained in the nest

[1] *Acknowledgments:* The investigation was made possible through the cooperation of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Dr. F. C. Craighead, in charge, and Mr. R. C. Brown, in charge of the New England area, arranged for quarters in their laboratories at Lake Clear Junction, New York, and in addition Forest Insect Investigations provided the funds necessary to carry on the work during the month of June. The Division of Forest Insect Investigations was conducting intensive studies on the spruce budworm outbreak in the Adirondacks and the entomologists on the scene graciously provided equipment, space and often transportation as well as valuable information on insect populations, bird parasites, and spraying operations. In addition they assisted in the difficult and tedious task of collecting budworm larvae and arranged for the shipment of cornborer larvae and pupae from New Jersey.

The New York State Department of Conservation arranged for additional laboratory space at their nursery at Lake Clear Junction. Mr. A. L. Foss and Mr. W. Smith who were actively engaged in conducting New York State's own investigations on the spruce budworm outbreak cooperated in every possible way to facilitate the present study.

Mr. David L. Kemp served as a technical assistant from June 19, to the completion of the study. He shouldered the bulk of the tedious duty of feeding the young nestlings in the laboratory.

undisturbed except for daily weighings and was fed only by its parents. In this way a measure of the effect of experimental feeding was obtained.

LABORATORY STUDY: (14 Nests).—In the laboratory study the nestlings developed under highly artificial conditions, but the nature and quantity of the food consumed by them could be controlled.

One nestling in each nest was designated as a *field check*. The *field check* remained in the nest and was undisturbed except for daily weighings. It was fed only by its parents and all nests were located outside of any DDT sprayed areas. The remaining nestlings were taken to the laboratory where they were fed experimentally.

The nestlings were kept in the laboratory for 3 days. On the first and second days they were fed as much as they could eat normally without resort to force feeding. On the third day, they were placed on a starvation diet of only 25 per cent of their body weight in food. Any nestlings that survived the 3 days in the laboratory were returned to their nests where they were permitted to complete their normal development if possible. After being returned to the nest they were undisturbed except for daily weighings. Of the nestlings taken to the laboratory one was designated as the *laboratory check* and fed normal insect food. The remaining nestlings were designated as *subjects* and were fed DDT killed or treated insect food.

COMBINED FIELD AND LABORATORY STUDY: (1 Nest).—In an effort to combine the field and laboratory studies nestlings were taken to the laboratory after several days of feeding in the field as part of the field study. In the laboratory the nestlings were placed on a starvation diet of 25 per cent of their body weight in food for 1 day. The *check bird* became the *laboratory check* when brought to the laboratory. The *field check* remained in the nest undisturbed except for daily weighings. The *laboratory check* was fed normal insect food while the *subjects* were fed DDT contaminated insect food. The purpose of this experiment was to determine whether the *subjects* might have stored DDT or otherwise been affected by DDT without manifesting any symptoms, but with the possibility still remaining that the birds might exhibit symptoms when starved.

NEST HUNTING AND OBSERVATION.—This activity was, of course, carried on throughout the study. Emphasis was placed on the smaller insectivorous birds of the spruce-fir forests as these were suitable for the study and were the birds most likely to be affected in large scale DDT spraying operations that might be made in an effort to control the devastating outbreak of the spruce budworm. For the purpose of this study it was best to find nests at an early stage of their development. The nests were undisturbed until the third or fourth day of the nestlings' life when experimental feeding generally was begun. Earlier than the third day of its life the nestling was very weak and difficult to feed properly. Delaying experimental feeding longer than the fourth day would have cut the period of study to only a few days in each nest. In all, 70 nests were found and 24 were selected for study.

NESTLING FOOD.—The food used in

**Table 1.—Tabulation of 5 nests studied during 1945 by R. T. Mitchell.**

| FAMILY: SPECIES | NESTLINGS | NO. DIED | PER CENT BODY WT. FED DAILY | REMARKS |
|---|---|---|---|---|
| Troglodytidae | | | | |
| House Wren | 7 | 0 | 10 to 15 | 4 subjects, 3 checks |
| Parulidae | | | | |
| Prairie Warbler | 4 | 2 | 10 to 20 | 2 checks lived, 2 subjects died, cause unknown |
| Fringillidae | | | | |
| Field Sparrow | 3 | 0 | 10 to 20 | 1 check, 2 subjects |
| Chipping Sparrow | 2 | 1 | 15 to 20 | 1 check lived, 1 subject died, cause unknown |
| Chipping Sparrow | 3 | 0 | 10 to 25 | 1 check, 2 subjects |

experimental feeding consisted of spruce budworm larvae and corn borer larvae and pupae.

The *check* nestlings in the field and *laboratory check* nestlings in the laboratory were fed normal insect larvae. These larvae were not contaminated with DDT in any way. The spruce budworm larvae were collected from spruce and fir trees. The trees were beaten with poles and the larvae fell on canvas sheets from which they were gathered. The corn borer larvae and pupae were reared by the Division of Forest Investigations at Moorestown, New Jersey, and shipped to Lake Clear Junction, New York.

The *subjects* were fed insect food that had been treated with DDT. These DDT contaminated larvae received DDT treatment in one of three ways: airplane spray, blower, and hand sprayer. One lot of sprayed budworms was collected from canvas sheets spread in a spruce-fir forest on June 16, 17 and 18, 1946. This plot received an aerial application of 1 pound of DDT per acre on June 16, 1946. The spray solution was 1 pound of DDT dissolved in 2.5 pints of xylene plus enough Number 2 fuel oil to make a gallon. A slight amount of red dye was added to facilitate evaluation of the spraying operations. Conditions were ideal and the spray distribution was excellent.

A second lot of sprayed budworms was collected from canvas sheets spread in a spruce-fir forest on June 18, 19 and 20, 1946. This plot received an application of 1 pound of DDT per acre on June 18, 1946. The spray solution was the same as that used in the aerial application but was applied by a blower from the ground. Conditions were unfavorable and spray distribution was irregular.

A third lot consisting of spruce budworm larvae and corn borer larvae and pupae was hand sprayed at the rate of one pound of DDT per acre. After being chilled, the insects were spread on a 0.0001 acre tray forming the bottom of an enclosed chamber. 0.3785 ml. of spray solution (described under aerial application above) was diluted with enough kerosene to make 3.785 ml. This was sprayed on the 0.0001 acre tray covered with insects The red dye in the solution facilitated covering the tray with an even application. Conditions were ideal and spray distribution was excellent.

All the food was stored in properly labeled, large, sealed vials placed in sealed mason jars. The jars were immersed in a brine-ice solution that maintained a fairly uniform temperature of 36° F. When taken from storage for actual use, the proper food was divided into individual nestling rations by weight and then each ration was placed in a small vial and labeled. During the early part of the study the nestling ration was kept on ice until a minute or so before feeding. The chilled food was found to be objectionable to the nestlings and during the remainder of the study the food was permitted to warm to room temperature prior to feeding.

FEEDING AND WEIGHING.—Feeding the nestlings was done with the aid of curved, fine-pointed forceps. If possible the nestlings were allowed to remain in the nest or nest box while being fed. Separate forceps were used for feeding the *check* nestlings, the *subject* nestlings, and for removing the almost inevitable fecal sac which followed the feeding. Normally, no force feeding was resorted to.

Most weights were taken in grams to the nearest hundredth. In some cases the birds were taken to the laboratory to be weighed; in other cases it was necessary to weigh the birds in the field.

LABORATORY PROCEDURE.—In the laboratory the nestlings were kept in labeled nest boxes. The nest boxes were either one-half pint or pint ice cream containers lined with packing material. Further to facilitate identifying the individual nestlings, colored, celluloid bands or colored ribbons were placed around the right leg of the nestlings. This was, of course, a necessity in the field study where the nestlings remained in their nests. In addition, the feathers of the nestlings were sometimes stained with picric acid. When the birds were large enough they were banded with Fish and Wildlife Service bands.

The improvised incubator was merely an insulated box heated with an electric light bulb and kept at from 85° F to 100° F. depending on the age of the nestlings

DISCUSSION AND SUMMARY OF DATA.—The data obtained during the course of this study have been deposited in the files of the Patuxent Research Refuge, Laurel, Maryland. They are too voluminous for this publication. Some of the data are summarized, discussed and interpreted here.

FIELD STUDY.—The data gathered dur-

**Table 2.—Nests studied in DDT field experiment—feeding level 25 per cent.**

| FAMILY: SPECIES | NEST NUMBER | NUMBER NESTLINGS | NUMBER DEAD OR MISSING | CAUSE OF DEATH OR ABSENCE |
|---|---|---|---|---|
| Parulidae | | | | |
| Nashville Warbler | 9 | 5 | 0 | — |
| Nashville Warbler | 12 | 4 | 4 | 3 predators<br>1 desertion |
| Chestnut-sided Warbler | 4 | 3 | 0 | — |
| Redstart | 35 | 4 | 0 | — |
| Fringillidae | | | | |
| Chipping Sparrow | 8 | 2 | 0 | — |
| Chipping Sparrow | 17 | 2 | 0 | — |
| Chipping Sparrow | 30 | 4 | 3 | 3 exposure |
| Field Sparrow | 23 | 4 | 1 | 1 accidental exposure |
| Total 8 Nests | | 28 | 8 | 8 |

ing the field study are summarized in tables 2 and 3. Table 2 presents the data for the eight nests in which the nestlings were fed experimentally at a level of 25 per cent of their body weight in insect food each day.

There was no apparent evidence of DDT toxicity noted when the nestlings were fed experimentally at a level of 25 per cent of their body weight in insect food each day. Both the *subjects* and the *check* of nests Nos. 9. 4, 35, 8 and 17 developed normally without any significant differences between them. All left the nests in a normal fashion.

Three nests suffered nestling mortality but none of the nestlings appeared to suffer from DDT poisoning. In nest No. 30, chipping sparrow, the three nestling *subjects* did die and the *check* alone survived. The cause of the death of the three *subjects* is felt to be due to exposure. Abnormally high temperatures were experienced during the study of this nest. That DDT toxicity manifested itself during the period of low nestling vigor and contributed to the death of the three *subjects* remains a possibility.

Histological studies were made of the Nashville warbler said to have died through desertion, one of the three chipping sparrows, said to have died of exposure, and the field sparrow likewise said to have suffered an accidental death. All slides showed irregularities of liver tissue but atypical of DDT toxicity as recognized at the present time in liver tissue.

On the basis of the data obtained in this study, nestlings of normal vigor can consume each day, from the third or fourth day of their life until they leave the nest, 25 per cent of their body weight in spruce budworm larvae killed by DDT applied at the rate of one pound per acre without manifesting any apparent signs of DDT toxicity when the nestlings remain in their nests and are cared for and also partly fed by their parents.

Table 3 presents the data for the two nests in which the nestlings were fed experimentally at a level of about 50 per cent of their body weight in insect food each day.

There was no apparent evidence of

**Table 3.—Nests studied in DDT field experiment—feeding level 50 per cent.**

| FAMILY: SPECIES | NEST NUMBER | NUMBER NESTLINGS | AVER. DAILY PER CENT WT. FED | NO. DEAD OR MISSING | CAUSE OF DEATH OR ABSENCE |
|---|---|---|---|---|---|
| Tyrannidae | | | | | |
| Alder Flycatcher | 25 | 4 | 54 | 0 | — |
| Bombycillidae | | | | | |
| Cedar Waxwing | 49 | 5 | 41 | 2 | 1 organic weakness (F.C.)<br>1 organic weakness and possibly DDT(Yellow) |
| Total 2 Nests | | 9 | | 2 | 2 |

DDT toxicity noted in the study of nest No. 25, alder flycatcher. The development of the *subjects*, *check*, and *field check* was uniform. Nor was there any apparent evidence of DDT toxicity in the study of nest No. 49. The *field check* died as a result of its organic weakness which was evident at all times. The *subject* "Yellow" was also a weak bird and probably died for the same reason; but that DDT toxicity manifested itself during the period of low nestling vigor and contributed to the death of the subject remains a possibility.

On the basis of the data obtained, nestlings of normal vigor can consume daily about 50 per cent of their body weight in corn borer larvae hand sprayed with DDT at the rate of one pound DDT per acre without manifesting any toxic effects. However, the data obtained are insufficient. This study was, of course, a logical step when it became apparent no toxicity was exhibited when nestlings were fed 25 per cent of their body weight in DDT killed insects each day. Unfortunately, not enough suitable nests were available for this study. Additional data especially from the study of warblers, vireo and sparrow nests is necessary before final conclusions can be drawn.

LABORATORY STUDY.—The data gathered during the laboratory experiment is summarized in table 4.

Three nests, No. 40, red-eyed vireo; No. 44, chipping sparrow; and No. 50, song sparrow, present clear-cut evidence of the toxicity of DDT. The three laboratory *checks* and the two *field checks* of these nests completed their normal development, whereas the five *subjects* died from DDT poisoning. Two other *subjects*, a redstart from nest No. 15, and a red-eyed vireo from nest No. 33, also died from DDT poisoning. In addition, DDT poisoning apparently contributed to the death of eight other *subjects*.

Thus DDT intoxication was the direct cause of death in 7 of the 27 *subjects* studied, and apparently contributed to the death of 8 others.

Table 5 presents a summary of nestling fate in the laboratory study. The death of 60 per cent of the laboratory *checks* as compared with 30 per cent of the *field checks* reflects the hazards and retarded development the nestlings suffered in the laboratory. It is hoped that in future studies improved techniques will make laboratory conditions more comparable with those that actually exist in the field.

The average daily per cent gains in weight for nestlings during the first 2 days

**Table 4.—Summary of DDT laboratory study.**

| FAMILY: SPECIES | NEST NUMBER | NUMBER NESTLINGS | No. DEAD OR MISSING | CAUSE OF DEATH OR ABSENCE | | |
|---|---|---|---|---|---|---|
| | | | | DDT | Possibly DDT | Other |
| Tyrannidae | | | | | | |
| Kingbird | 53 | 3 | 0 | — | — | — |
| Turdidae | | | | | | |
| Hermit Thrush | 47 | 4 | 3 | — | — | 1 LC[1] Retarded development in lab.<br>2 Subj. Retarded development in lab. |
| Bombycillidae | | | | | | |
| Cedar Waxwing | 24 | 5 | 2 | — | 1 Subj. | 1 FC[2] Unknown |
| Vireonidae | | | | | | |
| Red-eyed Vireo | 33 | 3 | 2 | 1 Subj. | — | 1 LC Unknown |
| Red-eyed Vireo | 40 | 3 | 1 | 1 Subj. | — | |
| Blue headed Vireo | 51 | 4 | 4 | — | 1 Subj. | 1 LC Retarded development;<br>1 Subj. Retarded development;<br>1 FC Desertion? |
| Parulidae | | | | | | |
| Redstart | 15 | 3 | 3 | — | 2 Subj. | 1 LC Accidental |
| Redstart | 15 & 18 | 2 | 2 | 1 FC-Subj. | — | 1 FC-LC Ectoparasites |
| Redstart | 18 | 3 | 3 | — | 1 Subj. | 1 LC Accidental; 1 Subj. Unknown |
| Redstart | 45 | 2 | 2 | — | 1 Subj. | 1 LC Unknown |
| Fringillidae | | | | | | |
| Chipping Sparrow | 44 | 4 | 2 | 2 Subj. | — | — |
| Chipping Sparrow | 55 | 4 | 3 | — | — | 1 LC, 2 Subj. Exposure |
| White-throated Sparrow | 39 | 4 | 3 | — | — | 1 LC, 2 Subj. Retarded Development |
| Song Sparrow | 50 | 3 | 2 | 2 Subj. | — | — |
| Song Sparrow | 56 | 5 | 3 | — | 2 Subj. | 1 FC Organic Weakness |
| Total | 14 | 52 | 35 | 7 | 8 | 20 |

[1] LC—Laboratory Check.
[2] FC—Field Check.

of study in the laboratory experiment were: *field checks* 44 per cent; *laboratory checks* 16 per cent; *subjects* 4 per cent.

At times, however, the laboratory conditions were very satisfactory and the laboratory check chipping sparrow, of nest No. 44, gained 83 per cent in weight in one day in the laboratory. This comling passerine birds fed on DDT killed or treated insects (sprayed at the rate of 1 pound per acre) exhibit signs of DDT poisoning in the majority of cases and in the laboratory, at least, can receive lethal doses. Possibly flycatchers and cedar waxwings are less sensitive to DDT toxicity than vireos, warblers, and sparrows.

**Table 5.—Causes of death of nestlings in the laboratory study.**

| Cause of Death | Field Check 10 | Lab. Check 15 | Subject 27 | Total 52 | Per Cent |
|---|---|---|---|---|---|
| 1. DDT Toxicity | — | — | 7 | 7 | 20.0 |
| 2. Possible DDT Toxicity | — | — | 6 | 6 | 17.1 |
| 3. Organic Weakness and Possible DDT Toxicity | — | — | 2 | 2 | 5.6 |
| 4. Organic Weakness | 1 | — | — | 1 | 2.9 |
| 5. Retarded Development in the Laboratory | — | 3 | 5 | 8 | 22.9 |
| 6. Ectoparasites | — | 1 | — | 1 | 2.9 |
| 7. Accidental | — | 2 | 0 | 2 | 5.7 |
| 8. Exposure | — | 1 | 2 | 3 | 8.6 |
| 9. Predators | — | — | — | 0 | 0.0 |
| 10. Desertion | 1? | — | — | 1? | 2.9 |
| 11. Unknown | 1 | 2 | 1 | 4 | 11.4 |
| Total Deaths | 3 | 9 | 23 | 35 | 100.0 |
| Per Cent Mortality | 30 | 60 | 85 | 67 | |

pares favorably with the maximum gain recorded for the *field checks*, which was 178 per cent for the *field check* kingbird of nest No. 53 during 2 days for an average of 89 per cent per day.

Had the *subjects* maintained a high degree of vigor in the laboratory the toxicity of DDT might have had less effect.

The degree of vigor seems to determine the type of symptoms manifested and the length of time the birds can survive despite their obvious poisoning. However, even when in excellent vigor the nestlings can die from DDT intoxication. An account of the symptoms of DDT intoxication is given later.

There seems to be some evidence to indicate flycatchers and waxwings are less affected by DDT than other birds. The alder flycatchers, nest No. 25, survived heavy feeding in the field, and the kingbirds, nest No. 53, survived the laboratory feeding. *Subjects* of nest No. 24, cedar waxwings, also survived the laboratory feedings, and the *subjects* of nest No. 49, cedar waxwings, showed no positive effects when fed in the field.

On the basis of the data obtained, nest-

COMBINED LABORATORY AND FIELD STUDY.—Since no evidence of DDT toxicity was apparent in the field studies and, on the other hand, numerous cases of DDT toxicity were noted during the laboratory studies, this combined study was a logical development.

The method employed was to feed higher doses in the field and, if the birds still showed no evidence of DDT toxicity, to then take them to the laboratory and place them on a starvation diet for a day or so. This would do two things: lower the vigor of the bird and force it to use up any reserve fatty tissue. Thus the cumulative effect of DDT, if any, and the relation between nestling vigor and DDT toxicity could be tested. It is hoped that future studies can be made to provide additional data on the points outlined above.

Only the *check* and *subject* "Green" from nest No. 49 were studied as part of a combined field and laboratory study.

Green appeared to be developing normally under field feeding but when taken to the laboratory for a day and fed only 25 per cent of its body weight in DDT

treated insects it died without having developed any symptoms of DDT poisoning. The laboratory check of the same brood survived through the same starvation test although it did not appear healthier and weighed only one gram more than green. Cross sections of the liver of the nestling show evidence of congestion which is unlike necrosis from chronic DDT poisoning.

SYMPTOMS OF DDT TOXICITY.—The *subject* nestlings reacted to DDT in a variety of ways. The reaction seems correlated with the species, vigor, size and development of the nestling. Some species, as already pointed out, showed little effect from their diet of DDT, while other species reacted violently.

Vigor, size and development all contribute to the hardiness of the nestling and determine its degree of endurance. This in turn, shapes the nature of the nestlings reaction to DDT. Weak birds, small in size, retarded in development, die quickly and relatively quietly. Vigorous, developed nestlings exhibit violent nervous tremors while they maintain strength to do so.

A synthetic account, based on the subjects of this study that manifested definite apparent symptoms of DDT toxicity follows. In general this account would be typical only of the more vigorous nestlings.

Most of the first day, the bird would appear normal with a tendency toward abnormal activity at the end of the first day. The bird would feed very readily and seemed always to be hungry. Perhaps a slight nervous tremor would be noted when the bird was active. When undisturbed the bird would rest quietly and easily with no tremors.

The second morning nervous tremors would be noted whenever the bird was active. It would feed violently and cheep frequently. As a measure of strength it would stand on its toes, hold up its head, and open its mouth on fully extended neck when feeding.

The nervous tremors would increase in violence during the second day until finally they might become constant and uninterrupted. Even when the bird is relatively inactive and undisturbed, the head and neck bob, the wings quiver, the body trembles and occasionally the legs jerk spasmodically. The tremors are too rapid to count but might be estimated at several times per second. It is difficult to feed the bird because the head bobs back and forth so rapidly. The bird never seems to be fully fed and will beg nervously for food at the slightest disturbance. Yet, because of the abnormal activity of the bird it gains very little weight or even loses weight while eating more than its weight in food each day. Feather development is equal to that of normal nestlings while the subject maintains its vigor. This, together with the low body weight makes the bird look more fully feathered than normal nestlings.

On the third day the bird's abnormal activity and nervous tremors continue unabated and the drain on its resources is reflected in loss of weight. It still feeds vigorously and is strong enough to feed while standing on its toes, neck and head fully outstretched.

Gradually the bird loses strength and in a few hours it can no longer stand on its toes to feed. It raises its head and neck slowly and before it can be fed the head sinks back to rest. The bird's wings are half extended and flutter incessantly, the body trembles and the head and neck bob rapidly, occasionally the legs jerk spasmodically. Finally, the bird becomes very weak and can no longer raise its head for food. It lies on its abdomen with its head down, partially supported by its half extended wings. The body, legs, head and neck begin to stiffen and the bird becomes cold to touch. Only the wings quiver. Even now, the bird will struggle desperately in a vain attempt to attain the feeding position when its nest box is tapped. If food is placed in its throat it can still swallow slowly. In an hour or so the bird dies quietly.

SUMMARY.—1. A study of the effect of DDT upon nestlings was conducted at Lake Clear Junction, New York, from June 3, 1946, to August 6, 1946.

2. Twenty-four nests were selected as suitable for study to determine the effect of feeding DDT contaminated insect larvae and pupae to nestling birds.

3. The problem was divided into a field study and a laboratory study.

In the field study the nestlings were fed in their nests and developed normally except for the experimental feeding and daily weighings. Ten nests were handled in the field study. In eight nests twenty-

eight nestlings were fed 25 per cent of their weight in food each day. In two other nests nine nestlings were fed about 50 per cent of their weight in food each day. In both cases experimental feeding was begun on the third or fourth day of the nestling's life and was continued until they left the nest. The parents provided additional food and all care required by the nestlings. There was no apparent evidence of DDT toxocity.

In the laboratory study the nestlings were taken to the laboratory on the third or fourth day of their life. They were fed as much as they desired the first two days in the laboratory. On the third day they were placed on a starvation diet of 25 per cent of their weight in food. Fourteen nests containing 52 nestlings were handled in the laboratory study. Any nestlings that survived the three days in the laboratory were returned to the nest to complete their normal development if possible. The death of 20 per cent of these subjects was attributed to DDT toxicity, and 22.7 per cent more exhibited signs of DDT poisoning.

4. In each study check birds were fed normal insect food, and subjects were fed DDT killed or sprayed (at the rate of 1 pound per acre) insect food. The insect food consisted of spruce budworm larvae and corn borer larvae and pupae.

5. There was some evidence to indicate that flycatchers and waxwings are less subject to DDT toxicity than vireos, warblers and sparrows.

CONCLUSIONS.—The application of 1 pound of DDT per acre to spruce-balsam forests in the Adirondacks in the experimental control of the spruce budworm was not sufficient to exterminate the insects in the sprayed area, and nestling diet therefore consisted of both sprayed and unsprayed insects. The field tests simulated these conditions. Therefore healthy nestlings would not be likely to succumb to DDT toxicity in areas of this kind to which a dosage at the 1 pound level is applied.

When nestlings were fed in the laboratory with sprayed material exclusively and suffered a loss in vigor from a starvation diet they were definitely susceptible to DDT toxicity. It is not unreasonable to assume therefore that if a large forested area were treated with DDT at a rate sufficient to eradicate the insect population at the time when young are being fed in the nest that they, being fed poisoned insects just subsequent to spraying, and not receiving sufficient food later through a scarcity of insect life, would suffer or succumb from DDT toxicity itself or from a combination of weakness and toxicity. —6-8-47.

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## PACIFIC SLOPE BRANCH MEETINGS

**Dates for the 1948 Annual Meeting for the Pacific Slope Branch of the Association have been set for June 14, 15 and 16. The meetings will be held in Vancouver, British Columbia and the headquarters will be the Hotel Vancouver.**

# The Control of Chiggers in Woodland Plots[1]

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In a previous paper (1944) the authors reported on preliminary experiments conducted in 1943 on the control of chiggers in woodland plots. The plots were small, 100 to 200 square feet in area, and promising results were obtained with sulfur, dinitro-*o*-cresol, and DDT. In further experiments on larger plots conducted in 1944, 1945, and 1946 these materials did not give satisfactory results, but two other materials, hydroxypentamethylflavan and benzene hexachloride, were very effective. These experiments, which are described in this paper, were conducted in heavily wooded areas near Savannah, Georgia.

The abundance of chiggers in the experimental plots was measured by collecting them on a piece of black oilcloth, 1 foot square, folded loosely once so that the unfinished surface was on the inside. The oilcloth was placed in favorable locations, such as on stumps and pieces of dead wood and at the bases of live trees. If chiggers were present, they ran onto the oilcloth and moved about as if in search of a host. After 1 minute the oilcloth was removed from the ground and spread out, finished surface up, on a small black table. The chiggers were easily observed running over the surface of the oilcloth and table, and were counted as they were removed with a wet needle or were crushed. Two species of chiggers were present, *Eutrombicula alfreddugesi* (Oud.) and *Acariscus masoni* (Ewing), the former predominating.

EXPERIMENTS IN 1944.—In 1944 experimental plots from 850 to 1000 square feet in size were used. Ten 1-minute collections were made in each plot, before treatment and at intervals for several days after treatment.

Four plots were treated with a dust containing 10 per cent of DDT in pyrophyllite. Dosages of 1.9, 5.7, 6.4, and 6.5 pounds of DDT per acre were applied with a rotary hand duster. Control was not satisfactory in any of the plots; the infestations after treatment ranged from 4 to 43, 55 to 84, 29 to 138, and 22 to 65 per cent, respectively, of the original infestations. Observations were continued for 8 to 16 days after treatment.

Five plots were treated with dusting sulfur (not conditioned or wettable) at rates of 13, 22, 63, 64, and 65 pounds per acre. Control was reasonably satisfactory only with the 65-pound dosage, the infestations after treatment ranging from 7 to 31, 31 to 99, 11 to 24, 23 to 54, and 1 to 13 per cent, respectively, of the original infestations. Observations were continued for 8 to 16 days after treatment.

A dust containing 5 per cent of dinitro-*o*-cresol in pyrophyllite applied at the rate of 3.2 pounds of dinitro-*o*-cresol per acre gave satisfactory control of chiggers for a short period, but caused severe injury to the vegetation.

EXPERIMENTS IN 1945.—In 1945 the experimental plots ranged in size from 2.5 to 10 square rods. Eight 1-minute collections were made in the 2.5 square rod plots and 10 in the larger plots each time counts were made. The infestation of chiggers in the plots was moderately heavy, averaging 11.5 chiggers per minute for 328 collections made before treatments were applied. There were 29 collections in which no chiggers were taken, 181 in which there were 1 to 10, 67 with 11 to 20, 44 with 21 to 50, 5 with 51 to 100, 1 with 153, and 1 with 174. The collections included 2751 specimens of *Eutrombicula alfreddugesi* and 349 specimens of *Acariscus masoni*;[2] 676 specimens were lost or crushed in collecting and handling.

Both sprays and dusts were used. Dimethyl phthalate, benzyl benzoate, dibutyl phthalate, *Thanisol*, and benzene hexachloride were always used as sprays. DDT, wettable sulfur (conditioned), sulfur (not conditioned or wettable), and derris were always applied as dusts. Hydroxypentamethylflavan was used both as a spray and as a dust. The sprays were applied at the rate of 160 gallons per acre (1 gallon per square rod) and the dusts at various rates. None of the ma-

[1] This work was conducted in part under a transfer of funds from the Office of the Surgeon General, U. S. Army, to the Bureau of Entomology and Plant Quarantine.

[2] Determinations by the junior author.

terials was injurious to vegetation in the amounts used.

The sprays containing dimethyl phthalate, benzyl benzoate, and dibutyl phthalate were prepared by adding 1 fluid ounce of emulsifier[1] (an aralkyl polyether alcohol) per 5 fluid ounces of acaricide, and emulsifying in water. *Thanisol*, an emulsifiable preparation containing 70 per cent of *Thanite* (mainly isobornyl thiocyanoacetate), was emulsified in water without the addition of any other material. In the test on August 22 the benzene hexachloride spray was prepared by dissolving 2.5 ounces of the crude material (gamma isomer 10 per cent) in 1 fluid ounce of emulsifier and enough xylene to make 1 pint and emulsifying in water. In later tests 8 fluid ounces of xylene and 1 to 2 fluid ounces of emulsifier were used per ounce of benzene hexachloride.

A dust containing 10 per cent of DDT in pyrophyllite was applied at the rate of 100 pounds per acre. The sulfur, wettable sulfur, and derris were applied as dusts without dilution.

The hydroxypentamethylflavan (or, more definitely, 2′-hydroxy-2,4,4,4′,7-pentamethylflavan) spray applied on July 24 was prepared by dissolving 5 ounces of this compound in 10 fluid ounces of xylene and 2 fluid ounces of emulsifier and emulsifying in water. In later tests a water-dispersible powder carrying 25 per cent of hydroxypentamethylflavan was mixed with water. The dust applied on August 3 contained 8.33 per cent of hydroxypentamethylflavan in pyrophyllite, and that used in the later tests contained 12.5 per cent.

The control obtained with various acaricides is shown in table 1. The abundance of chiggers in the untreated plots varied greatly from day to day. In general the percentage of the original infestation collected after treatment was more likely to remain high when the original collection was small. As similar fluctuations presumably occurred in the treated plots, small differences in abundance after treatment cannot be taken to show the actual degree of difference between materials. However, consistently low abundance after treatment, particularly less than 10 per cent of the original, indubitably represents actual control.

Hydroxypentamethylflavan gave promising results. As a spray it gave excellent control at 5, 4, and 2 pounds per acre throughout the periods of observation, or as long as 58 days; at 12 and 16 ounces per acre the results were less clear-cut. As a dust it was effective at 4 and 8 pounds per acre, but not at 1 pound.

Benzene hexachloride gave excellent control at 5 and 2 pounds per acre, but not at 1 pound, and at 12 ounces the results were doubtful. The material used in these tests had an unpleasant musty odor, which was strong in the treated plots as long as 29 days after treatment, even though many rains fell during the period. There was a slight indication that the residual action of benzene hexachloride was not so prolonged as that of hydroxypentamethylflavan.

In one test sulfur and wettable sulfur at 100 pounds per acre were effective for the entire period of observation, 29 days, but in another, wettable sulfur at 104 pounds was fairly effective for only 15 days, as were both materials at 48 pounds per acre.

*Thanisol* at 8 and 16 pints per acre was effective for a few days.

Dimethyl phthalate, benzyl benzoate, and dibutyl phthalate at 5 pints per acre, DDT at 10 pounds per acre, and derris at 16 pounds per acre were not satisfactory.

There was apparently no difference in the resistance of the two species of chiggers to the acaricides.

EXPERIMENTS IN 1946.—Experiments were conducted in 1946 to compare the fectiveness of benzene hexachloride and hydroxypentamethylflavan as emulsions, suspensions, and dusts at dosages of 2, 4, and 8 pounds per acre. An effort was also made to determine whether the amount of active ingredient applied per acre or the concentration at which it was applied was applied was the dominant factor in determining the control obtained. Three additional materials,—technical chlordane,[2] a chlorinated camphene containing 67–69 per cent of chlorine[3] and diphenyl carbonate—were tested for the first time.

All experimental plots were 5 square rods in area, and ten 1-minute counts were made in each plot at each collection. Five of the counting sites were marked and used at every collection, and five

[1] *Triton X-100*

[2] *Velsicol-1068.*

[3] *Toxaphene.*

**Table 1.—Results of treatment with various acaricides for control of chiggers in woodland plots, 1945.**

| Acaricide | Rate of Active Ingredient per Acre | Chigger Count Before Treatment | Per Cent of Original Infestation Collected After Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 Day | 3–5 Days | 7–9 Days | 10–14 Days | 15–19 Days | 21–24 Days | 29–36 Days | 42–58 Days |
| *Treatments applied July 24* | | | | | | | | | | |
| Dimethyl phthalate | 5 pt. | 169(106–8)[1] | 61 | 80 | 89 | 74 | — | 159 | — | — |
| Benzyl benzoate | 5 pt. | 109(70–24) | 7 | 21 | 37 | 41 | — | 81 | — | — |
| Hydroxypentamethylflavan (spray) | 5 lb. | 105(87–0) | 0 | 3 | 11 | — | 11 | — | 7 | 9 |
| Check (no treatment) | — | 110(80–1) | 54 | 45 | 71 | 65 | — | 86 | 77 | 108 |
| *Treatments applied July 25* | | | | | | | | | | |
| *First locality:* | | | | | | | | | | |
| Dibutyl phthalate | 5 pt. | 122(103–1) | 8 | 18 | 18 | 36 | — | 54 | — | — |
| Check (no treatment) | — | 63(55–0) | 168 | 149 | 189 | 175 | — | 71 | — | — |
| *Second locality:* | | | | | | | | | | |
| *Thanisol* | 8 pt. | 138(108–6) | 1 | 9 | 19 | 36 | — | 67 | — | — |
| Check (no treatment) | — | 132(76–2) | 82 | 106 | 85 | 61 | — | 58 | — | — |
| *Treatments applied August 3* | | | | | | | | | | |
| Hydroxypentamethylflavan (dust) | 8 lb. | 98(86–1) | 4 | 1 | — | — | 0 | 2 | 0 | 0 |
| DDT | 10 lb. | 66(55–0) | 59 | 47 | — | — | 100 | 99 | 101 | 100 |
| Wettable sulfur | 104 lb. | 74(54–5) | 14 | 0 | — | — | 11 | 36 | 24 | 8 |
| Check (no treatment) | — | 44(35–0) | 91 | 214 | — | — | 143 | 155 | 259 | 70 |
| *Treatments applied August 22* | | | | | | | | | | |
| *First locality:* | | | | | | | | | | |
| Hydroxypentamethylflavan (dust) | 4 lb. | 269(91–126) | 1 | 2 | 2 | — | 3 | 0.4 | 1 | — |
| *Thanisol* | 16 pt. | 88(37–35) | 2 | 7 | 41 | — | 27 | 42 | 47 | — |
| Check (no treatment) | — | 95(85–2) | 98 | 89 | 79 | — | 125 | 43 | 60 | — |
| *Second locality:* | | | | | | | | | | |
| Hydroxypentamethylflavan (spray) | 4 lb. | 150(121–0) | 2 | 1 | 2 | — | 1 | 2 | 1 | — |
| Wettable sulfur | 100 lb. | 67(38–11) | 6 | 0 | 0 | — | 4 | 1 | 1 | — |
| Sulfur | 100 lb. | 64(53–0) | 2 | 2 | 3 | — | 6 | 2 | 3 | — |
| Benzene hexachloride | 5 lb. | 105(91–2) | 0 | 0 | 3 | — | 11 | 5 | 7 | — |
| Check (no treatment) | — | 64(47–12) | 113 | 113 | 148 | — | 144 | 177 | 86 | — |
| *Treatments applied August 24* | | | | | | | | | | |
| Hydroxypentamethylflavan (spray) | 1 lb. | 136(116–0) | 2 | 3 | 1 | 6 | 13 | — | — | — |
| Benzene hexachloride | 1 lb. | 150(108–14) | 3 | 43 | 50 | 10 | 71 | — | — | — |
| Check (no treatment) | — | 98(92–2) | 95 | 78 | 26 | 78 | 52 | — | — | — |
| *Treatments applied August 28* | | | | | | | | | | |
| Hydroxypentamethylflavan (spray) | ½ lb. | 104(61–29) | 6 | — | — | 9 | 0 | 4 | — | — |
| Benzene hexachloride | ½ lb. | 127(98–5) | 3 | — | — | 3 | 12 | 3 | — | — |
| Hydroxypentamethylflavan (dust) | 1 lb. | 52(38–4) | 38 | — | — | 27 | 17 | 12 | — | — |
| Check (no treatment) | — | 84(71–0) | 106 | — | — | 44 | 38 | 32 | — | — |
| *Treatments applied August 29* | | | | | | | | | | |
| Sulfur | 48 lb. | 117(97–2) | 14 | — | 15 | — | 1 | 23 | — | — |
| Wettable sulfur | 48 lb. | 177(105–21) | 5 | — | 12 | — | 2 | 21 | — | — |
| Check (no treatment) | — | 76(68–2) | 114 | — | 101 | — | 100 | 38 | — | — |
| *Treatments applied August 30* | | | | | | | | | | |
| Benzene hexachloride | 2 lb. | 252(193–24) | 0 | — | 0.4 | 2 | — | 2 | — | — |
| Derris (4% rotenone) | 16 lb. | 84(68–10) | 90 | — | 26 | 8 | — | 48 | — | — |
| Hydroxypentamethylflavan (spray) | 2 lb. | 115(94–0) | 3 | — | 1 | 2 | — | 0 | — | — |
| Check (no treatment) | — | 72(64–0) | 132 | — | 104 | 86 | — | 44 | — | — |

[1] The figures in parentheses are the numbers of specimens determined as *Eutrombicula alfreddugesi* and *Acariscus masoni*, respectively. Some specimens in each lot were crushed or lost in collecting and handling.

were taken at random at each collection. The chiggers collected before treatment and at intervals after treatment were kept in alcohol for determination. Determinations have not been completed, but all of the 708 specimens identified were *Eutrombicula alfreddugesi*. The area was several miles away from plots used in previous tests, where mixed infestations occurred, but it is probable that there are a few *Acariscus masoni* in this area also. Chiggers were abundant and fairly evenly distributed throughout the area.

The diphenyl carbonate spray was prepared by dissolving 2 ounces of diphenyl carbonate in 10 ounces of xylene, adding 2 ounces of emulsifier, and emulsifying in 3 gallons of water.

The benzene hexachloride suspensions were prepared from a water-dispersible powder containing 50 per cent of crude benzene hexachloride. The emulsions were prepared from a concentrate containing 10 per cent of benzene hexachloride, 80 per cent of xylene, and 10 per cent of *Triton X-100*, by weight. The gamma-isomer content of the benzene hexachloride was given by the manufacturer originally as about 20 per cent, but this was revised later to 12 per cent. The benzene hexachloride dust was a commercial preparation claimed by the manufacturer to

contain 5 per cent of benzene hexachloride of 10 per cent gamma-isomer content.

The hydroxypentamethylflavan emulsions were prepared from a concentrate containing 2 parts of hydroxypentamethylflavan, 4 parts of xylene, and 1 part of emulsifier by weight. The suspensions of this material were prepared from a water-dispersible powder labeled to contain "not less than 30 per cent" of hydroxypentamethylflavan, and the dosage was calculated on the assumption that it contained exactly 30 per cent. The hydroxypentamethylflavan dust was prepared by mixing 1 part of the water-dispersible powder with 5 parts of pyrophyllite to give a 5 per cent dust. The chlordane and the chlorinated camphene were employed as emulsions that were made from concentrates prepared at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine.

As the dusts contained 5 per cent of active ingredient, the total amount applied per acre in each case was 20 times the acre-dosage shown in the table. The sprays, on the other hand, were always applied at 96 gallons per acre, the concentration being varied to provide the desired acre-dosage, except in the tests of August 7 and 14. In these tests the plots were not treated with a precalculated dosage, but were covered completely, once only, with a light coverage at 0.3 and 0.75 per cent, and a heavy coverage at 0.3 per cent, and the weight dosage was calculated from the quantity of spray applied.

The details of the experiments are presented in table 2. Since abundance in most of the check plots stayed above or near 100 per cent of the original abundance during most of the period of observation, a marked reduction in the treated plots was probably due in large part to the treatment applied. In the latter part of September the chigger population in the check plots dropped rapidly, and the counts in the treated plots at this time are of questionable value.

For the first few days after treatment, hydroxypentamethylflavan and benzene hexachloride were about equal in effectiveness, giving high initial kills in all plots except the one dusted with 2 pounds per acre of the former. In the duration of effective control they were about equal when used in the same form and at the same strength. Emulsions gave the longest periods of control (0 to 6 per cent of original infestation) and dusts the shortest. At 8 pounds per acre all treatments were effective for the entire period of observation, about 8 weeks. The abundance with the hydroxypentamethylflavan dust was 9 per cent on the 16th day, but dropped below 6 per cent again on subsequent dates. At 4 pounds per acre both materials were effective for the entire period as emulsions, for 3 and 4 weeks as suspensions, and for 1 and 3 weeks as dusts. At 2 pounds per acre as emulsions benzene hexachloride was effective for the entire period of observation and hydroxypentamethylflavan for 4 weeks; both were effective for 2 weeks as suspensions; as dusts hydroxypentamethylflavan was effective for 1 week and benzene hexachloride was ineffective. In the plots treated at this dosage the counts were irregular and dropped below 6 per cent of the original on the last observation in September. Of the nine paired treatments two showed a longer period of control with benzene hexachloride and two with hydroxypentamethylflavan.

In the tests made on August 7 and 14 a light coverage of concentrated spray gave at least as good initial control, but shorter residual control, as a heavier coverage of dilute spray, even though the dosage was comparable.

When applied as emulsions, chlordane and the chlorinated camphene at 8, 4, and 2 pounds per acre gave control equal to that of hydroxypentamethylflavan at 4 pounds per acre throughout the period of observation, 17 days.

Diphenyl carbonate proved to be ineffective, and counts were discontinued after 27 days.

SUMMARY.—Experiments were conducted in 1944 on the control of chiggers, *Eutrombicula alfreddugesi* (Oud.) and *Acariscus masoni* (Ewing), in woodland plots 850 to 1000 square feet in area. DDT at 1.9 to 6.5 pounds per acre was not satisfactory. Sulfur gave satisfactory control in one plot at 65 pounds per acre but not in four others at 64 to 13 pounds per acre. Dinitro-*o*-cresol at 3.2 pounds per acre gave satisfactory control for a short period, but caused severe injury to the vegetation.

In 1945 the experimental plots ranged in size from .0156 to .0625 acre. Hydroxypentamethylflavan at 2 to 8 pounds per

**Table 2.—Results of treatment with various acaricides applied in different forms for control of chiggers in treated woodland plots, 1946.**

| Acaricide and Type of Treatment | Pounds of Active Ingredient per Acre | Chigger Count Before Treatment | Per Cent of Original Infestation Collected After Treatment | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st Week | 2nd Week | 3rd Week | 4th Week | 5th Week | 8th Week | 11th Week |
| *Treatments applied June 11* | | | | | | | | | |
| Emulsion: diphenyl carbonate | 4 | 337 | 18 | 80 | 88 | 158 | — | — | — |
| Suspensions: | | | | | | | | | |
| Benzene hexachloride | 4 | 605 | 0.5 | 2 | 5 | 13 | 13 | 23 | 9 |
| Hydroxypentamethylflavan | 4 | 302 | 0.3 | 2 | 6 | 6 | 12 | 21 | 11 |
| Dusts: | | | | | | | | | |
| Benzene hexachloride | 4 | 419 | 1 | 12 | 43 | 28 | 55 | 31 | 21 |
| Hydroxypentamethylflavan | 4 | 342 | 0.3 | 2 | 6 | 34 | 23 | 23 | 30 |
| Check (no treatment) | 0 | 98 | 181 | 262 | 231 | 134 | 101 | 72 | 80 |
| *Treatments applied July 5* | | | | | | | | | |
| Emulsions: | | | | | | | | | |
| Hydroxypentamethylflavan | 4 | 469 | 1 | 1 | — | 2 | 1 | 2 | 6 |
| Benzene hexachloride | 4 | 433 | 4 | 1 | — | 2 | 1 | 0.2 | 2 |
| Check (no treatment) | 0 | 346 | 168 | 146 | — | 99 | 84 | 223 | 127 |
| *Treatments applied July 17* | | | | | | | | | |
| Emulsions: | | | | | | | | | |
| Hydroxypentamethylflavan | 2 | 231 | 0 | 2 | — | 2 | 9 | 16 | — |
| Benzene hexachloride | 2 | 273 | 1 | 5 | — | 4 | 5 | 1 | — |
| Hydroxypentamethylflavan | 8 | 671 | 1 | 3 | — | 2 | 1 | 3 | — |
| Benzene hexachloride | 8 | 340 | 1 | 0.3 | — | 6 | 2 | 1 | — |
| Check (no treatment) | 0 | 147 | 121 | 111 | — | 63 | 44 | 50 | — |
| *Treatments applied July 24* | | | | | | | | | |
| Suspensions: | | | | | | | | | |
| Hydroxypentamethylflavan | 2 | 310 | 1 | 5 | 25 | 26 | 18 | 37 | — |
| Benzene hexachloride | 2 | 262 | 0 | 5 | 23 | 29 | 26 | 18 | — |
| Hydroxypentamethylflavan | 8 | 684 | 1 | 0.4 | 1 | 1 | 1 | 0.4 | — |
| Benzene hexachloride | 8 | 456 | 0 | 0.2 | 0.2 | 2 | 1 | 0 | — |
| Check (no treatment) | 0 | 173 | 73 | 103 | 106 | 123 | 135 | 84 | — |
| *Treatments applied July 31* | | | | | | | | | |
| Dusts: | | | | | | | | | |
| Hydroxypentamethylflavan | 8 | 449 | 4 | 4 | 9 | 5 | 4 | 2 | — |
| Benzene hexachloride | 8 | 333 | 0 | 3 | 4 | 2 | 2 | 1 | — |
| Benzene hexachloride | 2 | 223 | 3 | 14 | 35 | 19 | 13 | 4 | — |
| Hydroxypentamethylflavan | 2 | 166 | 18 | 8 | 16 | 7 | 5 | 4 | — |
| Check (no treatment) | 0 | 291 | 145 | 80 | 82 | 80 | 66 | 76 | — |
| *Treatments applied August 7* | | | | | | | | | |
| Emulsion: Hydroxypentamethylflavan 0.3% | 1.2 | 167 | 10 | 8 | 11 | 8 | 50 | — | — |
| .75% | 2.6 | 149 | 1 | 1 | 2 | 12 | 13 | — | — |
| .3% | 3.1 | 184 | 4 | 8 | 3 | 6 | 2 | — | — |
| Check (no treatment) | 0 | 332 | 81 | 124 | 67 | 63 | 64 | — | — |
| *Treatments applied August 14* | | | | | | | | | |
| Emulsion: Benzene hexachloride 0.3% | 1.3 | 237 | 0.4 | 3 | 17 | 32 | — | — | — |
| .3% | 2.8 | 250 | 0.4 | 0 | 4 | 8 | — | — | — |
| .75% | 3.5 | 187 | 0.5 | 2 | 6 | 20 | — | — | — |
| Check (untreated) | 0 | 102 | 102 | 86 | 101 | 110 | — | — | — |
| *Treatments applied August 26* | | | | | | | | | |
| Emulsions: | | | | | | | | | |
| Chlordane | 8 | 367 | 0 | 1 | 1 | — | — | — | — |
| Chlorinated camphene | 8 | 305 | 3 | 1 | 0 | — | — | — | — |
| Chlordane | 4 | 331 | 0.3 | 2 | 0 | — | — | — | — |
| Chlorinated camphene | 4 | 832 | 3 | 0.2 | 0.1 | — | — | — | — |
| Chlordane | 2 | 332 | 0 | 1 | 0.3 | — | — | — | — |
| Chlorinated camphene | 2 | 273 | 2 | 0.4 | 0 | — | — | — | — |
| Hydroxypentamethylflavan | 4 | 404 | 8 | 1 | 0.2 | — | — | — | — |
| Check (untreated) | 0 | 344 | 109 | 93 | 131 | — | — | — | — |

acre, and crude benzene hexachloride at 2 to 5 pounds per acre gave excellent control, but at 12 and 16 ounces per acre the results with both materials were inconclusive or unsatisfactory. Sulfur and wettable sulfur at 100 pounds per acre were effective for 29 days. At 104 pounds wettable sulfur was fairly effective for only 15 days, as were both materials at 48 pounds per acre. *Thanisol* at 8 and 16 pints per acre was effective for a few days. Dimethyl phthalate, benzyl benzoate, and dibutyl phthalate at 5 pints, DDT at 10 pounds, and derris at 16 pounds per acre were not satisfactory.

There was apparently no difference in the resistance of the two species of chiggers. However, *Eutrombicula alfreddugesi* was the dominant species.

In 1946 the experimental plots were .0312 acre in size. With hydroxypentamethylflavan and crude benzene hexa-

chloride, a dosage of 8 pounds per acre was sufficient to maintain a high degree of control with all treatments through the period of observation (about 8 weeks). At 4 and 2 pounds per acre, however, emulsions were distinctly the best and dusts the poorest. With emulsions, effective control was maintained with both materials at 4 pounds per acre, and with benzene hexachloride at 2 pounds; at the 2-pound dosage hydroxypentamethylflavan was ineffective after about a month. When suspensions or dusts were used, the duration of control at 4 pounds per acre was somewhat longer with hydroxypentamethylflavan; at 2 pounds per acre control was of short duration with both materials. A light coverage of concentrated spray, whether benzene hexachloride or hydroxypentamethylflavan, gave at least as good initial control as, but shorter residual control than, a heavier coverage of dilute spray.

Applied as emulsions, chlordane and a chlorinated camphene at 8, 4, and 2 pounds per acre gave control equal to that of hydroxypentamethylflavan at 4 pounds per acre throughout the 17-day period of observation. Diphenyl carbonate was ineffective at 4 pounds per acre.

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# Dispersion and Feeding Habits of *Anopheles freeborni*

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The distance that a malaria vector mosquito travels from its breeding places and also its feeding habits en route are important factors to the malariologist. These factors of the activities of *Anopheles freeborni* Aitken were studied in 1945 in central California.

Kligler & Mer (1930) working with *Anopheles elutus*[3] Edwards in Palestine attempted to measure the distance of fall dispersion by determining the number of adults, development of fat body, and malaria incidence up to 14 kilometers away from the breeding area. They found that as adults dispersed in September and October, malaria increased at the places most distant from the breeding zone. Mer (1931) working with *A. elutus* found 3 to 4 feedings necessary for maximum fat body deposition. In 1932, Kligler found *A. elutus* present only in February and in October and November at 7.5 miles from its breeding area. Such fall movement, according to him, was related to outbreaks of malaria in arid regions. He found that the spring movements of *A. elutus*, *A. superpictus* Grassi and *A. sergenti* (Theo.) did not extend over 2.5 kilometers, while the fall movements of these species extended at least 13 kilometers (8 miles) from the breeding places. Eyles' (1944) review of the literature regarding movements of anophelines emphasized the necessity of distinguishing between "effective" and "maximum" flight range. Wolfenbarger (1946) reviewed the literature concerning dispersion of small organisms. He plotted regression coefficients on semi-log paper to illustrate dispersion of many species. He cites various authors who found dispersal of *A. quadrimaculatus* Say to extend from 1 to 4 miles, depending on conditions of the various studies.

Purdy (1925) found adult *Anopheles freeborni* (his *A. occidentalis* D. & K.) most abundant in September in 1919 and 1920. In 1921 and 1926 Freeborn mentioned a spring migratory flight of *A. freeborni* and in 1932 he reported its migration in the fall. He found that the females occasionally fed on blood during the winter. Rees (1942) failed to induce overwintering females to feed in Utah.

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[2] The author is indebted to Dr. Stanley B. Freeborn, Univ. of California, for suggesting the above problem, and to Dr. Chas. H. Martin, Oregon State College, for assisting in editing the paper.

[3] This species is *Anopheles sacharovi* Edwards-Barraud according to Eyles (1944).

In 1945 Freeborn reported that *A. freeborni* migrated as far as 10 or 12 miles from their breeding grounds. No migration data were presented in the paper. Aitken (1945) considered the spring emergence as well as the fall migration to be dispersal flights.

Malaria vector dispersion from isolated breeding grounds may be measured directly by marking, releasing and recovery of females or by measuring population fluctuations at successive distances. Indirect measurement consists of malaria incidence data taken at locations distant from the breeding place of the vector.

In the present study, blood feeding was correlated with seasonal population dispersion fluctuations of *Anopheles freeborni* in California in order to learn more of the habits of this species during the fall and early spring. As Eyles (1944) has stated, an isolated breeding place is essential in carrying out direct observational studies of an anopheline dispersion. These requirements were met by the studies reported here.

The data reported in this paper were obtained at two locations in the Sacramento Valley. The first study area was shaped like an "L" with the bottom line reversed and with north at the top of the letter. The long leg extended for 26 miles from rice-field breeding grounds which were 10 miles east of Winters, southward through Dixon to a point 6 miles northwest of Rio Vista. Then the study line extended from the angle of the "L" northwestward for 13 miles to Suisun to complete the Dixon-Suisun study area. Farms with domestic animals were present throughout the study area. They were most frequent in the vicinity of Winters.

The rice fields were the isolated source of *Anopheles freeborni* in this first study. The few irrigated fields near Dixon were supplied with water from wells. None of this irrigation water produced anophelines, except a few *A. pseudopunctipennis* Theobald where drainage was slow. The only creek in the Dixon-Suisun area that contained water after July was Putah Creek, which flowed from Winters north of Dixon and eastward into the Sacramento River. Putah Creek produced *A. pseudopunctipennis* abundantly in midsummer and also a few *A. punctipennis* Say, but no *A. freeborni* adults were reared from that creek or its tributaries. The sloughs and bays along the lower Sacramento River between Rio Vista and Suisun produced only *Aëdes* sp. The numerous small creeks emptying into the sloughs produced a few *A. freeborni* and *A. pseudopunctipennis* in the spring but were dry by mid-summer. There was little possibility of *A. freeborni* entering the Dixon-Suisun area during the fall migration except from rice fields north of Dixon.

The second study area was in a line between the Yuba River and rice fields located 9 miles southwest of Yuba City. This region will be called the Yuba City area in this article. Farm houses and animals were closely and evenly located through all the area. *Anopheles freeborni* bred abundantly in the rice fields which were separated from Yuba City by 9 miles of intensively cultivated peach orchards. The study area extended in an east-west line from the rice fields through the orchards to the Yuba River 5 miles away. The orchards were flood-irrigated from wells and the water did not stand for more than three days at any time. There were no ponds or streams in the orchard area. *A. freeborni* larvae were not found along the muddy shores of the Yuba River, or in the two sloughs associated with the river at the edge of the study area. Yuba City and Marysville were 6 miles north of the mosquito inspection station nearest to the Yuba River. Intensive mosquito control activities northeast of those cities precluded migration of anophelines into the study area from any direction except the rice fields to the west. There were no local breeding places south of the study zone.

Population movements and feeding habits of *Anopheles freeborni* were studied by examining the females found in anopheline natural resting places.[1] These NRP were located in the dark cool corners of barns, sheds, and basements, as well as dark places beneath bridges and in large culverts. The ones used were those where anophelines were found resting in the daytime in the previous fall. In the Yuba City area the resting places were located about a mile apart. In the Dixon-Suisun study area they were located at 1.5 to 2-mile intervals. These varied in light intensity, humidity, and proximity to mammals. This variation could not be

[1]Referred to as "resting places" in the discussions.

avoided due to the scarcity of suitable resting places in the areas studied. The averaging of the data obtained from the various zones extending from the rice fields tended to neutralize differences and to smooth the population curves.

The examination of resting places for anophelines was generally done at weekly intervals except from the first week of March to the second week of July in the Dixon-Suisun study. Necessary routine inspections of other areas during this period showed no general movements of *Anopheles freeborni*. In the first 3 weeks of August, other duties prevented investigations in the Dixon-Suisun area, but observations were made in the Yuba City area. In some of the zones of the Dixon-Suisun study, more than 5 miles from the rice fields, only two or three resting places were examined until the dispersion started in the fall, so the four zones of figure 1 which were farthest from the breeding area had a small number of resting places examined before the dispersion and a greater number afterwards.

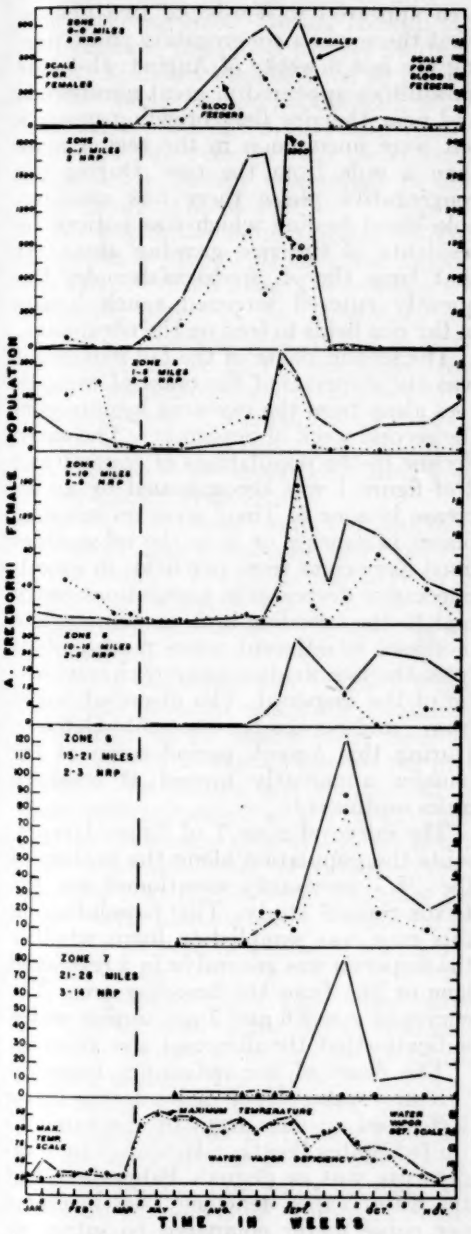


FIG. 1.—*Anopheles freeborni* dispersal and blood feeding in the Dixon-Suisun area. *Note:* The vertical dashed line indicates omission of the period from mid-March to mid-July.

During the study the same inspector made all of the observations with the aid of a flashlight and sucking tube. Blood-engorged females were counted at the time the mosquitoes were inspected for eggs, fat body, abundance and species. The mosquitoes were disturbed as little as possible and were returned alive to their resting place after they had been examined. Females were counted as blood feeders if half or more of their abdomens appeared red or black.

Both figure 1 and figure 2 record dispersal population data for successive zones extending from the rice field breeding grounds (zone 1) to the most distant part of the study areas (zone 7 of figure 1 and zone 4 of figure 2). For example, zone 1 of figure 1 was in the rice fields so it is labeled zero miles from the breeding grounds, while zone 2 extended to 1 mile away from the breeding area as shown in the zone legend. The legend for each zone shows the range in miles of the zone from the edge of the rice field and the number of NRP examined in each zone. Zone 1 of figures 1 and 2 shows the side of the chart bearing the scales for the female population (left) and the blood feeder population (right). The average resting place population curves for each zone were computed from several stations in that zone.

The studies of the Dixon-Suisun area showed noticeable local activity of *Anopheles freeborni* females in January and February, but no general movements between zones were found. The proportion of blood feeders was high in all zones studied at that time. Zones 5, 6, and 7

were not regularly examined in the spring months and their populations were not shown because in occasional observations there were very few anophelines present.

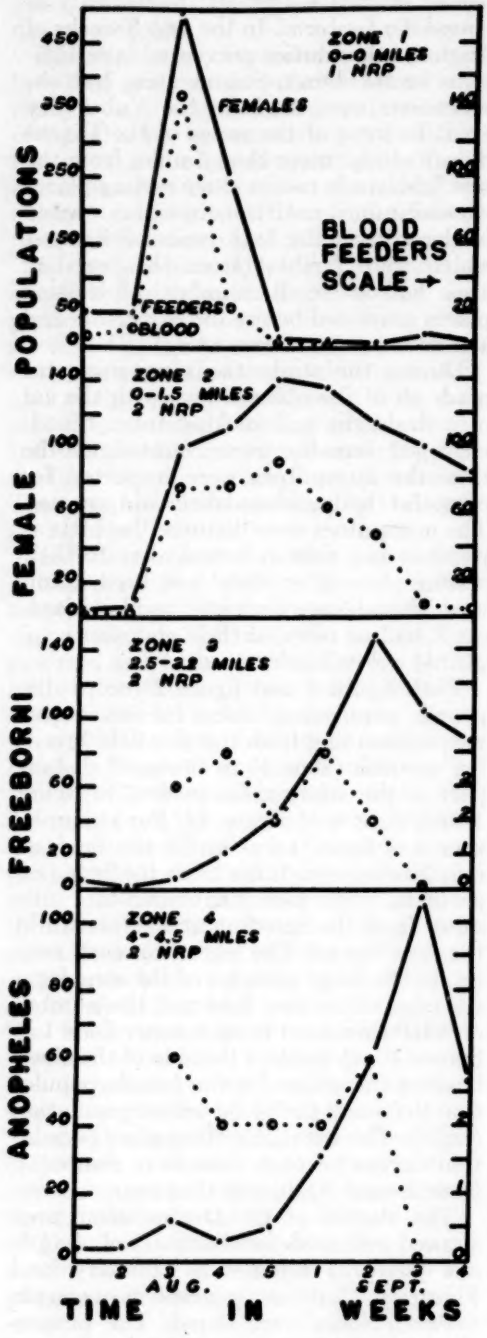


FIG. 2.—Dispersal and blood feeding of *Anopheles freeborni* near Yuba City.

Regular examinations of resting places in other nearby locations showed very low populations and no group movements of *A. freeborni* away from breeding areas between the first week of March and the second week of July.

The fall population movements of *Anopheles freeborni* in the Dixon-Suisun area appeared to consist of two phases. First there was a congregating phase during the last 3 weeks of August when the mosquitoes appeared in great numbers in and near the rice field breeding grounds but were uncommon in the region more than a mile from the rice. During the congregative phase there was considerable blood feeding which was noticed by residents of the rice growing areas. At that time the *A. freeborni* females frequently entered screened ranch houses in the rice fields to feed on the occupants.

The second phase of the fall movement was the dispersal of the mass of mosquitoes away from the rice area beginning in the second week of September. The sharp decline in the populations of zones 1 and 2 of figure 1 was accompanied by an increase in zone 3. There were no breeding places in zones 2 or 3, so the mosquitoes must have come from rice fields in zone 1. Successive decreases in populations proximal to the breeding area and immediate increases in adjacent zones more distant from the rice fields appeared characteristic of the dispersal. The dispersal lasted from mid-September to mid-October. During this 5-week period some of the females apparently moved at least 26 miles southward.

The curve of zone 7 of figure 1 represents the population along the bottom of the "L" previously mentioned for the Dixon-Suisun study. The population in this zone was sampled to learn whether the dispersal was general or in a restricted lane or line from the breeding area. The curves of zones 6 and 7 are similar which indicates that the dispersal was general.

The chart of the maximum temperature and water vapor deficiency in figure 1 is based on data from the Sacramento United States Weather Bureau. The temperature was in degrees Fahrenheit and the water vapor deficiency was in grams per cubic meter compared to saturated air. The weather data were smoothed by averaging daily records for each week to obtain the data recorded in figure 1. No

sharp deviations in temperature or air moisture content appear in the curves to correspond with the population movements of the mosquitoes.

The curves for the blood-feeding population in both areas follow in general those for the non-feeding populations. Blood feeding was common in and near the breeding areas. During the fall peak populations, the blood feeders plotted in zone 1 of figure 1 constituted 20 per cent of the total female population, 12 per cent for zones 2 and 3, and 8 per cent for zone 4. There were very few blood feeders found in this study more than 10 miles from breeding areas.

The population movements of the Yuba City area are simpler than those found in the Dixon-Suisun area. There was a congregating phase in the Yuba City area during the third week of August as shown in zone 1, figure 2. The dispersion from zone 1 was gradual and took place in the last two weeks of August. Zone 2 shows no sharp peak of dispersion, but zones 3 and 4 had peaks in the second and third weeks of September, respectively.

In the Yuba City study, the peak blood feeders of zone 1 consisted of 33 per cent of the females; in zone 2, they were 64 per cent, and in zones 3 and 4, they were respectively 2.3 and 5 per cent of the population.

During the study near Winters, female *Anopheles freeborni* mosquitoes containing either eggs or fat bodies were recorded. Freeborn (1932) first mentioned the presence of "fat bodies" in fall migrant females of that species. Aitken (1945) found that the fat body was well developed in overwintering forms. Freeborn (1945) reported that *A. freeborni* generally utilized winter blood meals to "build up the fat body" if kept in unheated rooms during the winter.

The well-developed eggs were visible through the wall of the female abdomen as two straw-yellow colored, faintly striated masses. The fat body appeared as a milky white mass which occupied most of the abdomen. Under a hand lens the fat body appeared as a pearl-white mass containing fine white threads and glistening globules of oil. The eggs changed from spherical to crescent shaped as they developed.

The legend for each zone in figure 3 shows the distance of the zone in miles from the breeding area and the number of resting places examined in the zone. The population of male and female *Anopheles freeborni* are shown above the horizontal dash line in each of the 3 zones, while the egg or fat body content of the females is shown below the dash line.

The curves in figure 3 refer to averaged data per resting place collected at successive distances (zones) southward from the rice field breeding areas. In zone 1, the curve for egg-containing females showed a peak during the fifth week of August and the third week of September with a sharp drop to zero between peaks in the second week of September. These peaks may indicate two late fall broods of *A. freeborni* which appeared 3 weeks apart. Freeborn (1926) found a mid-summer generation required 17 to 23 days to develop and the laboratory work of Herms (1943) showed a generation to be 21 to 22 days long. A few of the zone 1 adults dispersed in the fifth week of August into zone 2 which caused a sharp increase in the egg-contain-

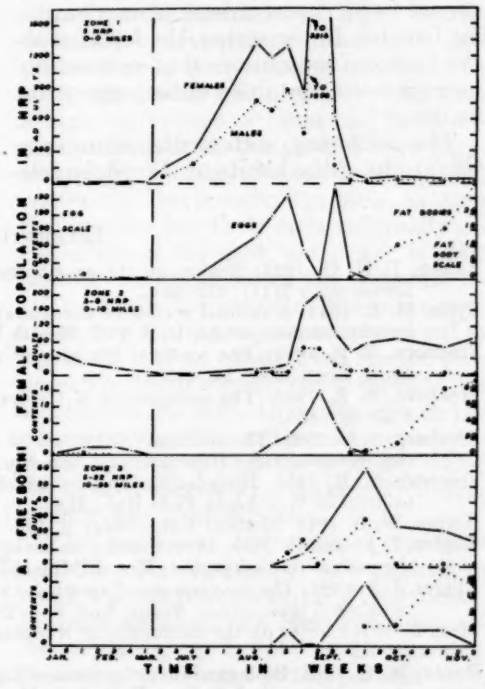


FIG. 3.—The relative fat body and egg content of *Anopheles freeborni* females at various distances from breeding areas. *Note:* No data were taken between the second week of March and the second week of July which is indicated by the vertical dashed line.

ing population of zone 2 in the second week of September. Only a few of the females dispersed as far as zone 3; a few of these females contained eggs. Eggs were found in zones 1 and 2 up to October 1; a few were found in zone 3 as late as the third week in November.

Freeborn (1932) states, "The fat body has invariably been the depository of the nutrients with the migrant form." He collected *Anopheles freborni* females near their breeding grounds in late October and November; these laid eggs when fed. In these studies no females which contained eggs were found in zone 1 after October 1. The first fat bodies were found during the fourth week of September in zones 1 and 2 and a week later in zone 3. All of the overwintering females contained only fat body material by the third week of November.

The dispersed females of zones 1, 2 and 3 contained eggs in September. At this time, there was no water available for oviposition. The eggs developed before there was deposition of fat. These same females later developed fat bodies which apparently replaced the eggs. Fat bodies appear to be characteristic of overwintering females. In the spring, the few *Anopheles freeborni* mosquitoes that successfully overwintered contained either eggs or fat bodies.

The following statements summarize this study of the habits of *Anopheles freeborni* in the Sacramento Valley of California:

No spring dispersal was observed, but blood feeding was noticeable at that time. Mass population movements were not found in the summer up to mid-July.

Fall population movements of *Anopheles freeborni* consisted of a congregative phase during the last 3 weeks of August in the immediate vicinity of the breeding area, followed in about a week by the dispersion phase in which the mosquitoes moved in large numbers definitely away from the breeding grounds into areas devoid of fall or winter breeding places. The dispersal phase took place during September and early October and was most striking within 10 miles of the breeding area. The dispersion extended eastward in the Yuba City study for at least 4.5 miles and southward in the Dixon-Suisun study for at least 26 miles.

Blood feeding was general during both phases of the fall movement. The area within 1.5 miles of the breeding grounds had the greatest percentage and greatest actual numbers of blood feeding females. No relation between the density of farms and blood feeding was apparent.

The females contained eggs during the dispersal. Hibernating females contained fat body. The few females which were able to overwinter contained either eggs, fat body or blood in February.

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# *Anthonomus vestitus* and Its Natural Enemies in Peru, and Their Importation into the United States

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*Anthonomus vestitus* Boh., a major pest of cotton in Peru, is attacked by several parasites, the most effective being a chalcidoid, *Catolaccus townsendi* Cwfd., and two braconids, *Triaspis vestiticida* Vier. and *Microbracon vestiticida* Vier.

The two braconids were reared and shipped to the United States in an effort to establish them on *Anthonomus grandis* Boh. in order that they might aid in the control of this serious cotton pest. The work was started in 1941 and continued through 1945, over a period of five seasons. During the routine work of collecting and rearing these parasites a considerable amount of data were accumulated on this host and its natural enemies in Peru.

METHODS.—The procedure followed in the collection of material for the rearing of parasites of *Anthonomus vestitus* depended on the physical condition of the material encountered. In 1941 the first lots of cotton buds were taken in Canete, a small valley about 135 kilometers south of Lima, which was dedicated exclusively to the growing of Tanguis cotton. According to E. J. Hambleton, then engaged as an entomologist to work on cotton pests for the Sociedad Nacional Agraria, the infested cotton buds remain on the plants for a considerable period, or even until development of the insects within them is completed. According to his experience, a higher parasitization occurs in the yellow and dry brown buds adhering to the plants, than in buds which have fallen to the ground. At his suggestion laborers were employed to pick the yellow and dry buds from the plants and to collect the buds from the ground. It was found in *Microbracon vestiticida* that more parasites were obtained in 1 hour from buds taken from the plants than from buds on the ground. In the case of *Catolaccus townsendi* the reverse was true. *Triaspis vestiticida* specimens were rarely found in the collections from Canete in 1941.

In northern Peru, in the areas of Piura and Sullana, cotton is grown in the Piura and Chira River valleys, the principal types being Pima and Acala. In both these types of cotton the majority of the buds fall to the ground within a few days after being punctured by *Anthonomus vestitus*. Very few of the infested buds turn yellow or dry up on the plant. In general those that do not fall to the ground appear to recover, especially from the feeding punctures. Collections of infested buds from the plants gave a high percentage of parasitization by *Triaspis vestiticida*, but practically none by the chalcidoids or *Microbracon vestiticida*. Selection of buds from the plants was not practical, however, as a great deal of time was required to detect the infested ones. It was found to be much better to employ laborers and have them gather all the buds from the ground. The best areas for these collections were those where parasitization was high, as determined by dissections of samples, and where a good proportion of the buds on the ground were still green, showing that a high percentage of them had fallen recently. Buds from the ground were parasitized by *Catolaccus townsendi* and *M. vestiticida*. This is understandable, as these two species lay their eggs externally on the larvae of the host, and there is little host development before the buds fall.

To obtain the parasites the buds were taken to a rearing room and spread out in layers on shelves constructed for the purpose. The room was darkened except for a window on one side. Upon emergence the parasites, together with many other insects, congregated on the window, where the desired species were collected for shipment to the United States.

The parasites, *Microbracon vestiticida* and *Triaspis vestiticida*, were packed in small wooden boxes about 5×7×9 inches, inside dimensions, one box of this size accommodating up to 1500 adult parasites. No immature stages of the parasite were shipped during the course of this work. Food was supplied in the form of honey, raisins, and water sweetened with sugar. Water was provided in small bottles into

[1] The writer acknowledges with thanks the aid received from the following workers: H. L. Parker for directing the project and helping in the preparation of the manuscript; E. J. Hambleton for helpful suggestions and aid in obtaining material; C. F. W. Muesebeck for identifications of the Braconidae; and E. J. Wille, José C. Lamas, and Manual J. Ramos for assistance in locating parasitized weevil infestations.

which a strip of cotton was introduced to serve as a wick. The neck of the bottle was plugged with cotton and a generous portion allowed to extrude from the opening, together with the wick, which was covered with cloth and tied sufficiently tight to keep the water from dripping out when the bottle was inverted. The water reached the cloth by capillary attraction and maintained a constant supply for the parasites for 10 days to 2 weeks.

All consignments were shipped via Panagra Airways, from Lima or Talara, Peru. Survival to destination was satisfactory and, with the exception of a few consignments, mortality en route was about the same as that in the laboratory in Peru for the same period. A summary of shipments of *Triaspis vestiticida* and *Microbracon vestiticida* is given in table 1.

**Table 1.—*Triaspis vestiticida* and *Microbracon vestiticida* shipped to various localities in the United States, 1941–45.**

| Year | Shipped to— | *Triaspis vestiticida* | | *Microbracon vestiticida* | |
|---|---|---|---|---|---|
| | | Colonies | Insects Shipped | Colonies | Insects Shipped |
| 1941 | Brownsville, Tex. | | | 14 | 4487 |
| | Tallulah, La. | 2 | 707 | 4 | 2845 |
| | Hoboken, N. J. | 2 | 402 | 2 | 235 |
| | Gainesville, Fla. | 2 | 626 | 1 | 37 |
| 1942 | Brownsville, Tex. | 8 | 9,498 | 5 | 66 |
| | Waco, Tex. | 8 | 16,007 | 5 | 509 |
| | Tallulah, La. | 9 | 16,837 | 3 | 306 |
| 1943 | Brownsville, Tex. | 3 | 2,480 | 2 | 190 |
| 1944 | Brownsville, Tex. | 24 | 28,944 | — | — |
| 1945 | Brownsville, Tex. | 15 | 13,861 | 6 | 234 |
| | Total | 73 | 89,362 | 42 | 8909 |

*ANTHONOMUS VESTITUS* BOH.—This species is considerably smaller than *A. grandis*. It feeds on the tender terminal shoots of the cotton plants, but also diverts its feeding activities to the squares as soon as they are formed. The adults fly well and apparently are able to disperse rapidly, spreading from one area to another within a few days. The female perforates the cotton square with her beak, then reverses her position and inserts her ovipositor into the hole, where she deposits a single egg well within the tissues of the buds. The egg cavity cannot be distinguished from the feeding puncture except by dissection. According to J. E. Wille (1943) the egg stage lasts 3 to 4 days. The larva passes its entire life within the cotton bud or square, molts four times, and changes into the pupal stage. Larval development requires 8 to 14 days, depending on climatic conditions. One to five larvae develop in a single cotton square, the number depending on the size of the square and the intensity of the infestation. The larva pupates and transforms into an adult in 5 to 12 days after pupation. The entire life cycle from egg to adult requires 16 to 30 days, and there are four to six generations a year in Peru.

José M. Lamas C. (1945) has presented data showing the increase in cotton bud weevils during the growing season of the plants. Development of the infestation varies from year to year, but in northern Peru the big increases usually take place between March and July. In southern Peru, where ratoon cotton is cultivated, the bud weevil infestation reaches its peak in February or March. For more detailed information on *A. vestitus*, the work of Lamas should be consulted.

*MICROBRACON VESTITICIDA* VIER.—The adults can be seen hovering around the cotton squares and are easily collected in the field. They are most active from 9:30 a.m. to 12 noon and fairly active from 3 to 6 p.m. on bright sunshiny days. On cool, cloudy, damp days they are most active from 11 a.m. to 2 p.m. The egg of *Microbracon vestiticida* is deposited externally on the larvae of *Anthonomus vestitus* within the cotton bud. The egg hatches within 2 to 3 days, and the larva feeds 4 to 5 or more days depending on the temperature. Development to adult requires 2 to 3 weeks in Peru during May and June.

H. D. Smith (1943) has reared *Microbracon vestiticida* on the bean weevil (*Acanthoscelides obtectus* (Say)) in the laboratory in the United States. At 70° F., development on this host required about 2 weeks, and the females lived 5 to 6 weeks.

Parasitization of *Anthonomus vestitus* by *Microbracon vestiticida* in Canete during the 1941 season was 10.5 per cent on May 12, and 25 per cent on July 5. These percentages were based on samples of 200 cotton buds each. Wille states that *M. vestiticida* parasitizes up to 10 per cent of the *A. vestitus*. His samples were taken over a large area and included areas other than Canete. Parasitization was notably lower around Lima or the Department of Callo, and no satisfactory locations for obtaining parasites were found, although there were good infestations of the weevils. In this work the areas having the highest parasitization were selected, and the data

therefore represent nearer the optimum than the average parasitization.

As has been noted in table 1, the large shipments of *Microbracon vestiticida* were made in 1941, and practically all were from Canete. Small numbers were obtained from the large collection of cotton buds in Piura in northern Peru, but this species was not sufficiently abundant to be considered a controlling factor of the bud weevil. During 1941–45, 8909 adults were shipped and liberated in various localities in the cotton-growing zones of the United States, including Brownsville, Tex., Tallulah, La., and Gainesville, Fla. This species has been recovered in the field in the season in which it was liberated, but is not known to have become established.

*TRIASPIS VESTITICIDA* VIER.—Adults were seldom observed in the field. When the parasites were confined in cages containing young larvae and eggs of *Anthonomus vestitus* on damp blotting paper, they paid no attention to these forms, but when infested cotton buds were introduced into cages, they became active immediately and began feeling over buds with their antennae, and started ovipositing within a short time. The adults live up to 20 days when fed on raisins, sugar water, and honey in the laboratory, but in all the experiments about 50 per cent died during the first 7 days and about 90 per cent were dead at the end of 2 weeks. The egg of *T. vestiticida* is deposited in the egg of *A. vestitus* and possibly in the young larvae, although it has been found only in the egg of the host. The egg hatches and the parasite larva develops within the weevil larva for a time, later emerging and apparently feeding externally for a short period before spinning its cocoon within the cotton bud. The life cycle of *T. vestiticida* from egg to adult required 2 to 3 weeks in Piura or northern Peru during July and August.

Parasitization by *Triaspis vestiticida* is usually low during the first part of the season, and does not increase noticeably until the *Anthonomus vestitus* population becomes rather dense. During the latter part of the season or from the end of June to the end of September, *T. vestiticida* increases rapidly in numbers and kills a high percentage of its host. The reasons for this are not understood, but there are at least a few possible explanations. First, no alternate host has been discovered, and it is possible that the parasite is so reduced in numbers, when the host larvae are scarce, that considerable time is required for it to build up to the effective numbers. Second, the bud weevil appears during the coolest months of the year, and it is possible that the cool weather has a greater retarding effect on the parasite than on the host. Third, it is possible that, when existing in small numbers, *T. vestiticida* does not have the ability to find its host.

Some examples of parasitization of *A. vestitus* by *T. vestiticida* will give an idea of the effectiveness of this parasite under good conditions. In 1942 a sample of 400 cotton buds was collected September 1 in a late planting of cotton, where high parasitization had been noted. Emergence from the lot consisted of 290 *T. vestiticida*, 8 *Catolaccus townsendi*, and 27 *A. vestitus*, indicating a parasitization of 89.2 per cent by *T. vestiticida*. In 1944 a sample of 200 cotton buds taken on August 15 had 47 *A. vestitus*, 41 *T. vestiticida*, and 4 *C. townsendi*, a parasitization of 44.6 per cent by *T. vestiticida*. A sample of 1100 cotton buds taken August 25 had 180 *A. vestitus*, 317 *T. vestiticida*, 76 *C. townsendi*, and 8 *M. vestiticida*, a parasitization of 54.6 per cent by *T. vestiticida*. These samples were all taken in areas that had been selected for the rearing of parasites for shipment and therefore represent the localities where the higher percentages of parasitization were prevalent. During the 4 years 1942–45 parasitization was higher in the upper part of the Chira River valley than in any other region surveyed. The reason for this has not been determined, but in any case the parasites were abundant and generally distributed throughout the cotton fields late in the season. Undoubtedly this contributed a great deal in reducing the number of beetles that carried over to the next season, thereby delaying the damage by the weevil until a majority of the bolls in early planted cotton had been formed. According to J. E. Wille (1943), *T. vestiticida* kills about 12 per cent of the *Anthonomus vestitus*, but his data were taken earlier in the season and over a longer period of time, as well as over a larger area than that reported on in this investigation. He also terminated his investigations earlier and did not have samples representing the height of parasite abundance.

During the course of this work *T. vestiticida* has been found in quantity only in northern Peru, and all parasites obtained for shipment to the United States were from material collected in the Chira and Piura River valleys and within 70 kilometers of Piura. As has been noted in table 1, shipments made for the 5 years 1941–45 totaled 89,362 adults. The majority of these arrived in the United States in good condition and were liberated in Texas, Louisiana, and Florida.

*CATOLACCUS TOWNSENDI* CWFD.—This species, recorded as *C. hunteri* in literature in the United States, is known as a parasite of *Anthonomus grandis*. The eggs of *C. townsendi* are deposited externally on the *A. vestitus* larva within the cotton bud. The larvae feed externally, from 1 to 3 or more developing on the same host larva, and then transform into pupae within the cotton bud, from which the adult parasite emerges. From 2 to 3 weeks are required for development from egg to adult. Few data were obtained on parasitization of *A. vestitus* by *C. townsendi*, but significant numbers of this species were obtained from practically all the collections from Canete and also from Piura. In Piura one collection of old cotton buds that appeared to have been on the ground for several days was dissected. The sample yielded 600 larvae of *A. vestitus*, of which 31, or 5.1 per cent, were parasitized by *C. townsendi*.

*Catolaccus townsendi* is more uniformly distributed throughout the cotton-growing sections of Peru than either *Triaspis vestiticida* or *Microbracon vestiticida*. The two latter species attain much higher percentages of parasitization in certain areas under proper climatic and environmental conditions, but they do not appear so early in the season or attain so uniform parasitization as does *C. townsendi*.

*EUPELMUS CUSHMANI* CWFD.—This species appeared in small numbers in the rearing cages and is probably parasitic on *Anthonomus vestitus*, but it occurred so infrequently as to be ineffective. Several lots of infested cotton buds were exposed to females for 5 to 7 days, but no oviposition was noted, nor were any parasites of this species reared from any of these lots.

A species of *Eupelmus* was also reared from this material, but no eupelmids emerged from the isolated buds, and no definite proof of them attacking *Anthonomus vestitus* was obtained.

*EURYTOMA TYLODERMATIS* ASHM. AND *EURYTOMA* SP.—*Eurytoma tylodermatis* and an unknown species of *Eurytoma* also appeared in the rearing cage frequently, but neither of these were reared from isolated cotton buds, or were they found during dissecting of cotton buds. These species may attack *Anthonomus vestitus* at times, but specific proof of their hosts was not obtained.

*PEDICULOIDES VENTRICOSUS* (NEWP.).—This species has been observed many times, and José M. Lamas C. mentions that it is a very effective parasite of *Anthonomus vestitus*, at times killing up to 20 per cent of the larvae, pupae, and adults. No attempts were made to obtain specific data regarding it, as it is well distributed in the United States.

SUMMARY.—*Anthonomus vestitus* Boh. is a major pest of cotton in Peru. It attacks the squares, and the larval development within them destroys the squares before they can develop into bolls. *A. vestitus* has three important parasites, *Catolaccus townsendi*, *Triaspis vestiticida*, and *Microbracon vestiticida*, which aid in its control. The last two species have been imported into the United States with the expectation that they will aid in the control of *Anthonomus grandis*. *Catolaccus townsendi* is present in the United States and is parasitic on *A. grandis*. *M. vestiticida* and *T. vestiticida* attack *A. grandis* and have been recovered from this host in areas where liberations have been made, but are not known to have become established. There are several other parasites that probably attack *A. vestitus* in Peru but, except for the predator *Pediculoides ventricosus*, which is abundant at times, they occur so infrequently as to be of little or no aid in its control.

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# Population and Control Studies of the Palau Gnat on Peleliu, Western Caroline Islands

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Soon after the occupation of Peleliu by the U.S. Armed Forces during the middle part of September 1944 it became apparent that the most annoying and harassing insect present was the biting Palau gnat, *Culicoides pelelioensis* Tokunaga. Most of the personnel on the island suffered from the irritating bites of this pest and everyone demanded that it be controlled.

Tokunaga & Esaki (1936) described the Palau gnat and made certain biological observations concerning it. The writer, while on Peleliu and confronted with the problem, did not have access to this literature or any literature that afforded specific information with regard to breeding habits or control methods pertaining to this gnat.

Preliminary observations were started early in October 1944 and on December 1, 1944 the program of gnat studies was initiated. This program was continued until November 20, 1945, at which time the writer left Peleliu to return to the United States.

Appearance Characteristics, Flight Habits and Distribution of the Palau Gnat.—The adult gnat is small (1.2 to 1.6 mm. in length) and presents a slightly hump-backed profile (Fig. 1.). The body is dark gray to blackish in color; the wings are light gray and are somewhat dappled in appearance when folded over the abdomen. The mouthparts are well developed for biting. The duration of the adult stage was not definitely ascertained, but it is believed to vary from seven to ten days.

The pupa is dark gray to blackish in color and varies in length from 2 to 2.4 mm. (Fig. 1). It is relatively inactive and rests in a vertical position at the water surface much of the time. The thoracic breathing tubes are well developed. The pupal stage is short; the full-grown larva, under laboratory conditions, can change to the pupal stage, pupate and emerge as an adult in less than twenty-four hours.

The larva is a slender, tapered, legless form that swims with a rapid, wiggling motion. The ivory colored body of a mature larva is approximately 18 mm. in length and consists of twelve segments. The terminal segment bears delicate, transluscent, hair-like processes probably of a respiratory nature (Fig. 1).

The egg (Fig. 1) is elongate, slightly curved and whitish; it is about 0.2 mm. in length. All eggs observed were dissected from a gravid female. The incubation period was not determined.

It is believed that the life-cycle of the Palau gnat is comparatively long, probably of many months duration, and that the periods of maximum gnat populations represent the progeny of successive broods of gnats. Rearing studies in the insectary were successful only in part, consequently the length of the complete life-cycle was not ascertained.

Craig & Faust (1945) state that *Culicoides* sp. eggs are laid in a single row in decaying vegetation in water. Patel (1921) found that in the case of *C. oxystoma* Kieffer the egg stage lasted from 3 to 11 days, the larval stage 2 to 10 weeks, the pupal stage 3 to 7 days and the adult stage probably a month. Edwards (1923) cites an example of *C. anophelis* Edwards in which an observation was made of the egg laying habits of an engorged female gnat; within two days time the female laid sixty-seven eggs around the edge of a bowl of liquid mud. Seven days later five pupae were observed in the bowl; each produced an adult in 3 to 4 days. Dove *et al.* (1932) in studies of the salt marsh sandflies *Culicoides* sp. believe that the larval period may be more than 6 months in length, the pupal period 4 to 7 days and the adult stage, under laboratory conditions 10 days.

[1] This work was completed while the writer was in the U. S. Navy, Medical Corps as Entomologist with Navy Epidemiology Unit 113. The expressions contained in this paper are personal ones and are not intended to represent official views of the Navy Department.

[2] The diligence and cooperation of Navy hospital corpsmen attached to Navy Epidemiology Unit 113 was commendable particularly with respect to their assignments in the Palau gnat program. Dr. John Paul Jones gave helpful criticisms of, and encouragement to, the program. The writer is grateful to Dr. Alan Stone, Division of Insect Identification, United States Department of Agriculture for verifying the identity of the Palau gnat. He is indebted to Dr. W. P. Hayes, Entomology Department, University of Illinois for his invaluable criticisms of this paper and to Dr. B. D. Burks, Illinois State Natural History Survey Division for his assistance with certain parts of the reference material.

The Palau gnat is a moderately strong flier under quiet weather conditions; its flight is discouraged both by a strong breeze and by rain. These gnats will fly as far as 2 miles with the aid of a slight breeze. *Culicoides* sp. have been collected by means of an airplane at altitudes of 200 to 13,000 feet, Glick. Henry Dybas, stationed on Saipan at the time, related to the writer that, on three different occasions, he had collected live adult

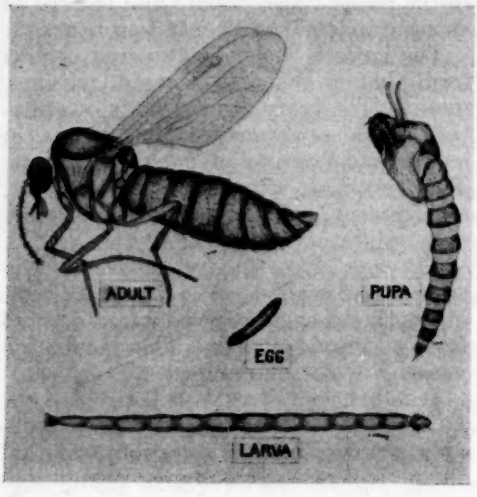


FIG. 1.—The Palau gnat, *Culicoides pelelioensis*.

Palau gnats from the interior of airplanes that had flown from Peleliu.

In the region of the Palau group of islands weather conditions vary little from one time of the year to another; it is believed that the slight seasonal differences that occur have but little effect on gnat populations. The average maximum temperature is 86° F.; the average minimum temperature (at night) is 76 ° F. and neither average temperature varies more than a few degrees during the year. The average annual rainfall is 150 inches with at least 3 inches in the driest month and over 10 inches of rain during each of the other months. The average relative humidity at night is 95 per cent and during the day it is 80 per cent.

The Palau gnat was observed by the writer to be present on the following islands in the Western Caroline group: Peleliu, Pulo Anna, Ngesebus, Garakayo, Ngeregong and Koror. It is probably present on Babelthuap though no surveys were conducted on this island.

THE PALAU GNAT AS A PEST.—Because of its small size and vicious biting habits this gnat is a serious pest. The gnats prefer to feed on the wrists, hands, arms, neck and ankles; they will crawl under sock tops, sleeve cuffs and collars to feed. The bites are extremely irritating and, in the case of most individuals, cause a large reddish weal. The weals itch intensely and may continue to do so for several days. Scratching of the bites resulted in numerous cases of secondary infections that developed into ulcerous conditions; some cases had to be hospitalized. The loss of sleep by personnel because of gnat bites during times of heavy gnat populations seriously affected their efficiency, particularly among aviation units. A few individuals were pecularily resistant to the effects of the bites and others developed varying degrees of immunity to their effects after being subjected to them for several months. The gnats usually do not bite immediately after coming to rest on the skin; they first select a location to their liking and then quickly start feeding. The approximate times of heaviest feeding are from 6:00 P.M. to 12:00 midnight and from dawn to 9:30 A.M. Hinman (1936) found that *Culicoides mississippiensis* Hoffman is most active in early evening though will readily attack man during the day. According to Neiva & Penna (1916) *C. guttatus* Coquillet is most active in the morning and less numerous during the evening; this is similar to the habits of *C. kiefferi* Patton & Cragg, observed by Patton (1913).

It is believed that the Palau gnat is not, at present, a vector of disease. During 13 months of observation no disease attributable to it was encountered though thousands of men were bitten repeatedly during this interval. Taylor (1944) found no evidence to indicate that Australian *Culicoides* transmit disease. Du Toit (1944) associated *Culicoides* sp. with the transmission of blue-tongue to sheep. According to Kinoshita (1918) the bites of *C. mihari* Kinoshita give rise to fever. Craig & Faust (1945) state that in Africa *C. austeni* Carter *et al.* and *C. grahami* Austen have been incriminated in the transmission of the non-periodic

filarial worm, *Acantho-cheilonema perstans* Manson, to man and that in South America *C. furens* Poey has been found to transmit a related filarial worm of man, *Mansonella ozzardi* (Manson).

SITES AND CHARACTERISTICS OF GNAT BREEDING.—The Palau gnat breeds primarily in decomposing organic material in the brackish, tidal, mangrove swamps. The larvae are most numerous in the top 2 inches of this material near the swamp margin. The organic material mixed with mud varies in depth from several inches to several feet and is inundated, or at least moistened, twice daily by the tides. Conversely it is drained or exposed twice daily by tidal action; when this condition exists the larvae and pupae lie relatively inactive in the loose organic material near the surface. Breeding was found to be heaviest in swamps or parts of swamps not exposed to the direct action of the tide. This was particularly true in inland, brackish, tidal swamps having a subterranean connection with the sea. The latter type of swamp was never entirely inundated and isolated pools of water usually remained even at low tide. Breeding in swamps exposed to the direct wind and wave action was restricted mainly to protected areas along the extreme margins.

A salinity survey of the water in all of the gnat breeding areas was conducted. Water samples were collected at both high and low tides from various regions in each swamp. The silver nitrate precipitation technique American Public Health Association Inc. 1943 was used to determine salinity values. The total chlorides of seawater in this region in parts per million is 43,750. Table 1 summarizes pertinent data concerning the salinity of principal swamp margins on the island.

**Table 1.—Salinity of the water along the margins of the principal gnat breeding swamps on Peleliu.**

| Swamp | Samples | Mean Total Chlorides P.P.M. High Tide | Mean Total Chlorides P.P.M. Low Tide | Differential Between High and Low Tides |
|---|---|---|---|---|
| 1 | 4 | 5,830.00 | 17,514.75 | 11,684.75 |
| 2 | 4 | 5,091.25 | 459.62 | 4,631.63 |
| 3 | 6 | 2,535.83 | 2,695.88 | 160.05 |
| 4 | 6 | 3,628.33 | 1,068.84 | 2,559.49 |
| 5 | 4 | 8,531.25 | 1,481.45 | 7,049.80 |
| 6 | 4 | 3,651.25 | 1,236.97 | 2,414.28 |
| 7 | 4 | 9,596.85 | 539.45 | 9,057.40 |
| 8 | 6 | 20,131.10 | 8,188.32 | 11,942.78 |
| 9 | 6 | 19,677.43 | 6,824.63 | 12,852.80 |
| 10 | 8 | 17,055.11 | 10,256.94 | 16,798.17 |

In general swamps having a chloride differential between 0 and 5000 supported heavy gnat breeding as determined by adult and larval surveys. The swamps with a range of chloride differentials between 5000 and 10,000 supported moderate to heavy breeding. Breeding in swamps with a range of chloride differentials between 10,000 and 14,000 was generally light to moderate. There was some local variation in breeding intensity in the various swamps because of individual variations of breeding sites within the different regions of the swamps. Gnat larvae were found in water with a total chloride range of 600 to 20,000 parts per million. The heaviest breeding occurred in swamps having a total chloride range of two thousand to five thousand parts per million at high tide.

Tokunaga & Esaki (1936) were of the opinion that the immature stages of the Palau gnat are passed in the mangrove swamps that surround Peleliu. They were correct to a certain extent, however, the heaviest gnat breeding occurs in protected inland brackish swamps.

The Palau gnat breeds throughout the year. Patel (1921) observed that *Culicoides oxystoma* Kieffer also reproduces during the entire year.

PERIODICITY OF GNAT POPULATIONS.—The Palau gnat exhibits a bi-monthly periodicity in its breeding habits. Twice each month there is a period of maximum and minimum gnat populations. Characteristically 2 to 3 days during and 2 to 3 days after a period of maximum population the gnats are extremely annoying. In the interval between maximum population periods (minimum population period) the gnats practically disappear. The time between maximum gnat population periods varied from 13 to 17 days. Occasionally there was a small, localized, secondary emergence period following the main emergence period because of unusual tidal or biological conditions or both. The gnats appear very rapidly on the night of maximum population density (fig. 2).

The maximum and minimum population periods are directly correlated with tidal conditions (Fig 2). Twice during the month the differential rise of the tides is small for intervals of several days. It is during these intervals that the gnats rapidly pupate and emerge in great num-

bers. Conditions are favorable for this because extensive marginal areas of swamps are not inundated or exposed to tidal action. Likewise there are two intervals during the month when the differential rise of the tides is comparatively large; at these times the gnat population is minimal. By studying tide tables in advance it was possible to predict the duration; 10 minutes were devoted to counting gnats at each station during each survey. The results of these population counts are presented graphically in figures 2 and 3.

Approximately 20 per cent more gnats were collected from the man in the dark than were observed on him in the light. The gnats were attracted to the lights

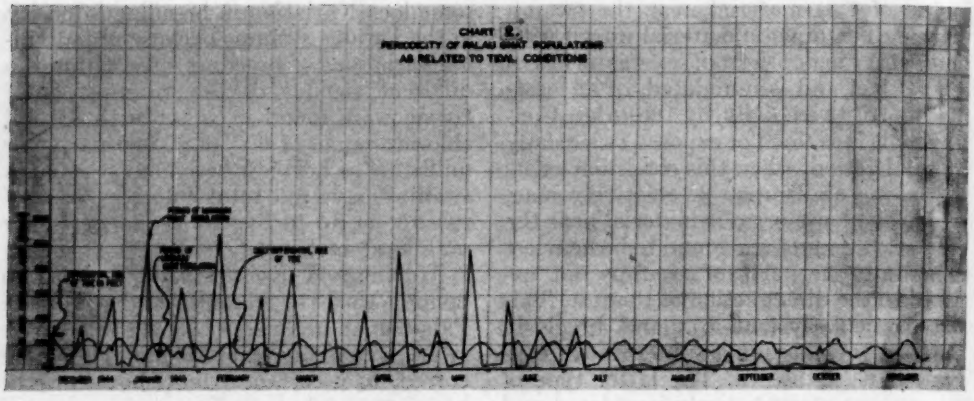


FIG. 2.—Periodicity of Palau gnat populations as related to tidal conditions.

periods of maximum and minimum gnat populations each month to within a day or two of the actual times. This was of some value in planning control operations.

Tokunaga & Esaki (1936) also observed that the Palau gnats appear several days before a new or full moon and that they persist for about a week.

THE PALAU GNAT SURVEY.—An adult gnat survey was started on December 1, 1944 and was continued until November 20, 1945. Ten counting stations were established; these stations were distributed over the island and were located adjacent to gnat breeding sites. The same stations were used throughout the survey.

The gnat counts were made at night beginning at dusk when the gnats were most active. A man wearing only shorts was placed in the path of the lights of a car (engine turned off); two other men observed him carefully killing and counting the gnats as soon as they came to rest on his skin. This procedure was repeated in the dark after turning off the car headlights and moving the man about 100 feet away from the site of the count in the light; a flashlight was used intermittently for the purpose of observing the gnats. Each observation was of 5 minutes

of the car and flew around them in a confused manner. Hinman (1936) found that *Culicoides mississippiensis* is attracted to lights.

Light studies were conducted in July, August, September and October 1945 to determine if one color was more attractive to the gnats than another. Red, blue, yellow, green and clear globes were used on gasoline lanterns. On nights of heavy adult gnat populations these lights were taken to various gnat breeding sites. They were placed one hundred yards apart and observed simultaneously for thirty minutes. The Palau gnats attracted to each light were counted. The results of these studies were not significant statistically, but it was interesting to see that the intense, clear light attracted more gnats than all of the other colors.

A larval survey was initiated on December 15, 1944 and was completed on January 20, 1945; this survey included all of the principal gnat breeding sites. Larvae were numerous in swamps 2, 3, 4 and 6 and in localized regions of 9 and 10. They were less readily collected in the other breeding areas. Results of subsequent larval surveys conformed very closely with those of the original one.

Palau gnat larvae can be collected best by visiting a typical breeding site at low tide. Press a dipper against the surface of the decomposing organic material of the swamp bed and allow the water to seep into the dipper. If gnat larvae are present in that location they will be concentrated and transported by the water entering the container.

THE PROBLEM OF PALAU GNAT CONTROL.—The control of the Palau gnat on Peleliu presented many problems. The tidal swamps constitute at least one fourth (2,000 acres) of the total acreage of the island. They are so located that no part of the island is far removed from them. There are about 30 miles of gnat breeding swamp margins comprising approximately 500 acres. The vegetation, for the most part, is dense and many of the regions are practically inaccessible by foot or vehicle because of impenetrable vegetation and deep mud. Because of the sea-level elevation of most of the swamp areas drainage is not feasible and the entrances or mouths of the swamps are wide and exposed to the direct force of the sea. Dams or fills to exclude the sea from the swamps would involve a major engineering project. Several of the tidal swamps have no apparent connection with the sea; subterranean channels through the coral probably provide a connection.

Insecticides applied in most of the gnat breeding areas are disturbed twice daily by tidal action.

INSECTARY STUDIES OF PALAU GNAT CONTROL.—A series of simplified insecticide tests were conducted in the insectary from November 15, 1944 to January 20, 1945 to determine the efficacy of available insecticides in killing gnat larvae. The kinds of insecticides and the facilities for testing them were limited. The tests involved the introduction of 50 gnat larvae into a series of glass containers 120 c.c. size) filled with water from the breeding sites. The various insecticides were applied at different rates to the surface of the water. Diesel oil No. 2, diesel oil with 5 per cent DDT, DDT-xylene-*Triton* emulsion (3 per cent DDT), DDT-xylene-*Triton* emulsion (5 per cent DDT) and 10 per cent DDT larviciding dust were the insecticides used in these tests. The insecticides were applied at the rates indicated in table 2.

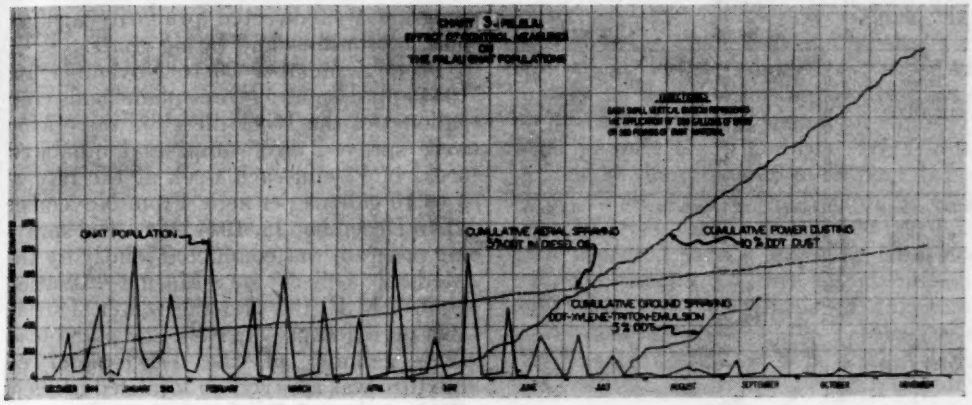


FIG. 3.—Effect of control measures on Palau gnat populations.

Oil and oily insecticides used in these tests were entirely inadequate against Palau gnat larvae. Dove *et al.* (1932) found this to be true in their studies of the salt marsh sand fly problem. In one of the tests with diesel oil No. 2 the surface of the water was covered with oil to a depth of one-half inch; the gnat larvae frequently swam into the oil, but it was 16 days before all of them were dead. The larvae were apparently normally active for the first 12 days and were sluggish during the last 4 days. The oil provided practically an airtight seal and the container was not disturbed during the entire period of 16 days. Palau gnat larvae apparently are well adapted to using combined oxygen in the water or else their oxygen requirements are small for it was not possible for them to breathe at the surface in this test. This particular test

**Table 2.—Insecticide tests against Palau gnat larvae.**

| Insecticide | Time Required to Kill Gnat Larvae | Rate of Application of Insecticide per Acre | Number of Days Larvae in Control Container Remained Alive |
|---|---|---|---|
| Diesel Oil #2 | 16 days | 2.08 gallons | 21 days |
| | 16 | 4.16 | |
| | 14 | 8.32 | |
| | 16 | 0.50 inch layer of oil | |
| 5% DDT in Diesel Oil | 12 days | 0.10 gallon | 18 days |
| | 12 | 0.20 | |
| | 12 | 0.40 | |
| | 10 | 3.36 | |
| | 11 | 6.72 | |
| | 10 | 13.44 | |
| | 10 | 26.88 | |
| DDT-xylene *Triton* Emulsion (3% DDT) | 6.0 hours | 2.10 gallons | 10 days |
| | 4.0 | 4.20 | |
| | 2.5 | 8.40 | |
| | 2.0 | 16.80 | |
| | 2.0 | 33.60 | |
| | 1.5 | 67.20 | |
| | 1.5 | 134.40 | |
| | 1.5 | 268.80 | |
| DDT-xylene *Triton* Emulsion (5% DDT) | 4.0 hours | 2.10 gallons | 14 days |
| | 2.0 | 4.20 | |
| | 2.0 | 8.40 | |
| | 2.0 | 16.80 | |
| | 1.5 | 33.60 | |
| | 1.5 | 67.20 | |
| | 1.5 | 134.40 | |
| | 1.5 | 268.80 | |
| 10% DDT Dust | 9.9 hours | 2 pounds | 10 days |
| | 9.5 | 4 | |
| | 9.2 | 6 | |
| | 8.0 | 8 | |
| | 8.0 | 10 | |
| | 7.5 | 12 | |
| | 6.2 | 15 | |

was repeated four times with essentially the same results each time.

Three per cent and 5 per cent DDT-xylene-*Triton* emulsion and 10 per cent DDT larviciding dust, both capable of permeating the mud and water, were effective in killing the gnat larvae.

Insect repellents did not give much protection against Palau gnats. A number of tests were made among night sentries, guards and other personnel on night duty, with the various insect repellents available, at that time, to personnel of the U.S. Armed Forces. These tests were made during periods of heavy gnat populations. Most of the guards and other personnel involved in these tests reported that they were heavily bitten regardless of the applications of insect repellents. Apparently dimethyl-phthalate gave the best protection, but this was not adequate. Head nets furnished very little protection because the gnats readily penetrated them. Spraying screens, bed nets, head nets etc. with 5 per cent DDT in kerosene afforded some protection, but when the gnats were numerous some of them would penetrate these treated surfaces and bite viciously regardless.

FIELD STUDIES OF PALAU GNAT CONTROL.—On September 20, 1944 an aerial spraying program was started; 5 per cent DDT in diesel oil weighted with lubrication oil was used. This program was at first under the supervision of the Senior Medical Officer[1] of the Second Marine Air Wing and the Officer in Charge[2] of the Epidemic and Malaria Control Unit, First Marine Division. This control program was directed primarily against flies, mosquitoes and biting gnats.

From September 20 to November 10, 1944 approximately three plane loads (750 gallons) of the DDT-diesel oil insecticide were sprayed on swamps and inhabited areas of Peleliu each week at the rate of 5 to 10 gallons per acre. From November 11 to December 15, 1944 this aerial spraying program was conducted jointly by the Medical Officer[3] of Marine Aviation Unit V.M.F. 134 and the writer. During this period approximately one plane load (250 gallons) of the DDT-diesel oil mixture was sprayed on localized areas of the swamps of Peleliu each week at the rate of 3 to 5 gallons per acre.

On December 16, 1944 the aerial spraying program was taken over by the writer and was continued by him until he left the island in November 1945. During the period December 16, 1944 to June 1, 1945 approximately 44 plane loads (11,000 gallons) of 5 per cent DDT in diesel oil oil were sprayed on localized mosquito and gnat breeding areas at the rate of 1 to 3 gallons per acre. Two and one half plane loads were applied every 10 days.

Satisfactory mosquito and fly control were accomplished early in October 1944, less than a month after the aerial spraying program was begun. From September 20, 1944 to June 1, 1945 despite the frequent and heavy aerial spray applications of DDT in diesel oil, there was no apparent reduction in the Palau gnat population (Fig. 3). The aerial spraying was also supplemented by a limited amount of ground spraying.

Upon completion of 6 months (December 16, 1944 to June 1, 1945) of aerial spraying experiments in field control of

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[2] Hugh O'Connel, (M.C.) U.S.N.
[3] R. J. Kressler, (M.C.) U.S.N.R.

the gnats, using the 5 per cent DDT-diesel oil mixture, and after reviewing results of insectary tests with the various insecticides previously mentioned, it was decided that oil or DDT in oil were not efficacious in controlling Palau gnat breeding. The aerial spraying program was continued on a limited scale, but only for the purpose of mosquito control.

The planes used for aerial spraying were *T.B.F.s* each equipped with a 250 gallon spray tank located in the torpedo bay. There was a series of nozzles under each wing tip and an outlet in the tail; a small pump forced the spray mixture out of the nozzles. The planes were flown at approximately 110 knots per hour at an altitude of about 100 feet. In spraying, the plane covered a swath varying in width from 100 to 150 feet depending on wind conditions. The pilots, of course, always sprayed with the wind as much as possible. The droplet size of the spray particles was determined by placing smoked glass slides in the swamp areas while the planes were spraying; the rather large droplets fell in concentrations of 40 to 60 per square inch.

Insectary tests had shown that DDT-xylene-*Triton* emulsion was effective in killing gnat larvae, but at this time the supply of this material was limited and also the use of it as an aerial spray was prohibited because of the flash explosion hazard.

An adequate supply of 10 per cent DDT larviciding dust was available so field tests using this material were started on April 15, 1945. At first, hand, rotary type dusters were used to treat the gnat breeding swamp margins; these hand dusters were also mounted on the rear end of jeeps to facilitate dusting operations in certain regions. It soon became evident that hand methods of application were inadequate because of the vastness of gnat breeding areas.

A small power duster was designed by the writer and was constructed by the U. S. Naval Construction Battalion Maintenance Unit 571 out of scrap materials. This duster (Fig. 4) consisted of a hopper (150 pounds capacity) equipped with mechanical and manual agitators; a sliding, perforated plate at the bottom of the hopper regulated the rate of delivery of the dust. The hopper was connected directly with an enclosed, turbine-type blower (8 inch fan) that was driven by a small gasoline pump engine at a speed of about 4000 R.P.M. A 3-inch (inside diameter), wire reinforced hose 7 feet in length was attached to the outlet of the blower; it could be directed in any position desired. This duster would blow the dust 75 to 100 feet and with a favorable breeze the dust would travel 100 yards or more.

The power duster was mounted on a light truck and on June 9, 1945 the power dusting program for the control of Palau gnats was started. A crew of three men, including the truck driver, operated this equipment. They could treat approximately 70 acres of swamp margins dur- an average work day using approximately 1000 pounds of 10 per cent DDT dust applied at the rate of 10 to 15 pounds per acre. About 7 days were required each time to treat the 30 miles (500 acres) of gnat breeding swamp margins. Rain frequently interrupted dusting operations. Approximately two thirds of the total gnat breeding areas could be reached with the duster; the road system of the island was good and it paralleled swamp margins in many regions. The duster truck was driven slowly along the edges of gnat breeding sites with the duster nozzle directed for optimum coverage of the breeding areas and for maximum penetration of the marginal vegetation. Dusting operations were always conducted with the wind. The power dusting program was continuous from June 9 to November 20, 1945 (Fig. 3).

Early in July 1945 a power decontamination sprayer (orchard sprayer type) with 400 gallons capacity was mounted on a 2.5 ton truck (Fig. 4) for use in applying DDT-xylene-*Triton* emulsion (one part emulsion four parts water) on gnat breeding sites. On July 20 the DDT-emulsion power spraying, field control tests were started. These tests supplelemented the regular DDT power dusting program; the same swamp margins were treated as those included in dusting operations. The rate of application of the DDT-emulsion was 3 to 5 gallons per acre. The sprayer was operated at approximately 500 pounds pressure. A nozzle producing a flat, fan-shaped spray with coarse spray particles was used. Most of the rubber gaskets, washers etc. in the new sprayer disintegrated badly within a 40 day

period; the xylene in the spray mixture probably was responsible for this.

The supply of DDt-xylene-*Triton* emulsion for power spraying was depleted on August 31; from September 1 to 18 local applications of the DDT-emulsion were made with hand, pressure sprayers. The DDt-emulsion field tests had to be discontinued on September 18, 1945, because of lack of material. Live gnat larvae were difficult to find in areas treated with DDT-xylene-*Triton* emulsion.

DISCUSSION AND SUMMARY OF FIELD CONTROL STUDIES OF THE PALAU GNAT.—Certain readers, particularly those interested in conservation and wild-life problems, may be concerned about the heavy rates of application of DDT in various forms on the gnat and mosquito breeding areas on Peleliu. The writer wishes to emphasize that at the time these studies and control operations were conducted it was his assignment and duty to afford the thousands of military personnel on the island the maximum protection possible against insect pests and insect vectors of disease. Under conditions of war there was little time to experiment with minimal rates of application of insecticides.

Continuous gnat and mosquito breeding surveys afforded the writer excellent opportunities to observe general conditions of the wild-life on the island. Birds became increasingly abundant; ornithologists collecting on Peleliu recorded at least 40 different species. Entomologists also found general insect collecting better on Peleliu than on many comparable islands. Fish and crabs were numerous in some of the tidal swamps receiving the heaviest applications of DDT; occasionally a very few dead fish and crabs were observed. The only known indigenous mammals present, bats and rats, apparently withstood the heavy applications of insecticides very well; had there not been an efficient rat control program in operation the rats would have been numerous.

The rates of application of DDT discussed in this paper are not necessarily recommended for general use, but are presented for the consideration of present and future workers in a similar field.

From December 15, 1944, to June 1, 1945, approximately 11,000 gallons of 5 per cent DDT in diesel oil were sprayed on gnat and mosquito breeding swamps by airplane; the rate of application was 2 to 5 gallons per acre. The applications were made at about 10-day intervals and only the areas supporting gnat or mosquito breeding, determined by surveys, were treated. During this period the average Palau gnat population index, determined by regular population counts at established stations, was 635.

The power dusting program was in full operation from June 9 to November 20, 1945 and it was directed specifically against gnat breeding. Ten per cent DDT larviciding dust was used; it was not diluted, principally because there were no satisfactory diluents available for experimentation. During this period approximately 62,000 pounds of 10 per cent DDT dust were applied on the gnat breeding swamp margins (30 miles comprising 500 acres) at the rate of 12 to 15 pounds per acre. There were 11 periods of maximum gnat populations all of which were comparatively low (fig. 3). The average gnat population index during this 6 months interval was 123. This population index is over 80 per cent less than the population index that prevailed during the preceding 6 months period of aerial spraying with 5 per cent DDT in diesel oil.

From the time of the initiation of the DDT power dusting gnat control program to the termination of this study 6 months later, there was never a time when the Palau gnats were as numerous as they had been before this kind of control program was started (Fig. 3); usually the gnat population was so low that gnats were not bothersome. There were occasional periods, in localized areas, when the gnats were noticeable, but considering the extensive breeding areas present the general gnat population was negligible when compared with the persistent, heavy populations that had appeared twice each month during the first 8 months of the occupation of Peleliu.

It is believed that this degree of gnat control was accomplished by the DDT dusting control program. The accessible breeding areas treated constituted only about two-thirds of all of the gnat breeding sites. If aerial dusting facilities had been available it is believed that approximately seven-eights of all the breeding sites could have been treated and the reduction of Palau gnat populations would have been correspondingly greater.

SUMMARY OF HABITS AND BREEDING CHARACTERISTICS OF THE PALAU GNAT.—Though the Palau gnat is a serious pest with vicious biting habits, it was not observed to be a vector of disease to man during the 12 months devoted to its study. The bites usually cause large, somewhat irregular, reddish weals that itch intensely. Scratching of the bites commonly resulted in secondary infections. Palau gnats prefer to feed on the neck, arms, hands, wrists and ankles. The approximate times of heaviest feeding are from late afternoon to midnight and from dawn to mid-morning.

The Palau gnat breeds primarily in decomposing organic material along the protected margins of brackish tidal swamps. Gnat larvae were collected in swamps having a salinity (total chlorides) range from 600 to 20,000 parts per million. The heaviest breeding occurred in swamps having a salinity range of 2000 to 5000 parts per million.

There is a bi-monthly periodicity in the breeding habits of the Palau gnat; this periodicity is correlated with tidal conditions. During the two periods each month when the differential rise of the tides is high the gnat population is low. Conversely during the two periods of the month when the differential rise of the tides is low the gnat population is high. The number of days between maximum gnat population periods varied from 13 to 17. The periods of maximum and minimum populations each month can be anticipated to within a day or two of the actual times by plotting graphically the differential rise of the daily tides (data from tide tables) for the entire month.

Weather conditions, with reference to temperature, rainfall and relative humidity in this region, do not vary much throughout the year; it is believed that the slight variations do not appreciably affect Palau gnat breeding.

Adult gnats are attracted at night by lights; the intensity of the light apparently is of more importance than its color in this reaction.

The Palau gnat is a moderately strong flyer under quiet weather conditions; with a slight breeze it can fly as far as 2 miles.

Palau gnats have been observed by the writer on the Western Caroline Islands of Peleliu, Ngesebus, Garakayo, Ngeregong, Koror and Pulo Anna. They probably are also present on Babelthuap. Live, adult specimens have been intercepted on three occasions at Saipan in airplanes arriving from Peleliu.

CONCLUSIONS CONCERNING THE CONTROL OF THE PALAU GNAT.—1. Diesel oil is not effective in controlling gnat breeding even when applied at excessively heavy rates.

2. Five per cent DDT in diesel oil is not effective in controlling gnat breeding.

3. Ten per cent DDT larviciding dust applied regularly on the water and mud of gnat breeding sites 3 to 5 days before the anticipated period of maximum population, at the rate of 12 to 15 pounds per acre, reduces the gnat population to the extent that it is not particularly troublesome to man.

4. If an agent could be added to the DDT dust mixture that would facilitate the sinking of the dust in the water and mud the efficiency of the dust would probably be increased.

5. Aerial dusting facilities for applying DDT dust on gnat breeding sites inaccessible to ground operations would have been invaluable in supplementing the ground, power dusting control program.

6. DDT-xylene-*Triton* emulsion spray (one part emulsion to four parts water) is effective in controlling gnat breeding when applied to the water and mud of the breeding sites at the rate of 3 to 5 gallons per acre. The coverage with this material is not as extensive or complete as when DDT dust is used.

7. It is desirable to remove as much of the dense, marginal vegetation as possible from the gnat breeding sites; this reduces the available resting places for adult gnats and enables insecticides to penetrate more effectively to the actual places of breeding.

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# Suppression of Insect Damage by Means of Plant Hormones

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In recent years there have been rapid developments in the investigation of plant growth-regulating substances. These materials produce at least several distinct manifestations on plants. Such changes have been, in general, directed toward modification of various types of tissue, including herbicidal action, root induction, parthenocarpy of fruit and inhibition of abscission layers.

Plant growth regulators now appear to play a role in the expression of insect damage to plants. Although a characteristic type of injury may frequently follow the presence of some unknown insect toxin, such disturbances have not been directly associated with plant auxin behavior. It is possible that in feeding, however, insects either may inject or may withdraw a substance which increases or decreases activity of response to growth substances. Thus they may cause a typical and characteristic tissue response.

Widespread application of the so-called plant hormones in horticultural practices followed the successful use of naphthalene acetamide to control preharvest drop of apples (Gardner *et al.* 1939). Further adaptations of these activators have been extended to weed control as well as many other practical uses. More recently Södnig *et al.* (1943) has reported an association between growth regulating substances in various amounts in diseased and healthy plant tissues. The fact that certain plant diseases are frequently dependent upon insects for dissemination would suggest a possible direct relation between insects and growth-regulating substances. There is no evidence to date, however, showing that such a relationship with insects does exist but it is of interest to note that Link (1940) was able to obtain curvature responses in the *Avena* coleoptile test (Went & Thimann 1937) with extracts of certain aphids and extracts of plant tissue upon which they have fed.

The literature relating to this subject indicates a relationship between insect damage and growth substance activity in plants. This suggestion is based upon (1) the similarity in growth changes in plants caused by hormones and insect feeding, (2) similarity in enzymic activity where it appears to be involved, and (3) the fact that certain bean plants treated with hormones failed to show the expression of insect damage after insect feeding.

SIMILARITY IN GROWTH CHANGES CAUSED BY INSECT FEEDING AND PLANT HORMONES.—Perhaps one of the most significant evidences that disturbances in plants caused by insects and by hormones are similar is the change in tissues caused

[1] Approved by the Director of the Wisconsin Agricultural Experiment Station.

by the feeding of insects and mite gall-formers. These physiological expressions in plants are very specific, so much so that frequently insect species can be determined from the type of gall they form. In general, it is the opinion of most workers that gall formation is caused by the introduction of substances into plant tissue. Felt (1936) states that stimulation by these substances is a fundamental principle in gall formation, and Martin (1930) concludes that since stem galls in sugar cane can be produced by injection of macerated leafhoppers, possibly auxins were involved. Formation of galls caused by insects is a tissue response paralleling the response to growth promoting substances (Brown & Gardner 1936) as in some plant tissues.

Further similarities in changes in plants caused by insects and by plant hormones may be seen in the development of deformative effects in plants. The occurrence of adventitious buds and reduction of length and width of internodes of plants may follow application of hormones (Greenleaf 1938; Thompson 1945). Ripley (1927) has reported that some mirids cause malformation in young trees and a witches broom is produced at the terminal leaf bud rather than a single stem. A disease associated with the feeding of a cercopid (Hardy 1927) on sugar cane has been described as reducing the length and width of plant internodes with a development of adventitious buds. A rosetting and shortening of internodes of alfalfa and clover by the feeding of spittle insects (Fisher & Allen 1947) has been recently recorded. Smolak (1933) describes a witches' broom of lilac caused by *Eriophyes lowi* (Nel). Psyllid yellows, which is associated with the feeding of *Paratrioza cockerelli* (Sulc) possesses symptoms that include rosetting of leaves in witches' broom fashion at the internode. Many abnormal tissue responses have been pointed out (Granovsky 1928; Hollowell *et al.* 1927; Monteith 1928) that show feeding of certain Empoasca species will cause stunting, rosetting and proliferation of dwarfed shoots. Carter (1939) observes a close analogy between the insect galls and the development of adventitious buds, and suggests that a possible relationship may exist between gall, hosts, and hormones. The statement by Carter that—"insects feeding on a specific plant species only" would suggest that auxin relations may be involved between insects and plants. It was also his opinion that if symptoms following certain insect feeding is "much more rapid than that of fungus or bacterial infection, this appears to be the principal support for the numerous suggestions in the literature that the secretions are toxic."

That the feeding of *Lygus* upon potato stems indicates systemic response or diffusion of a toxic principle in association with the feeding of the insect has been reported by Leach & Decker (1938). Smith (1920) concluded that while certain insects feed they inject toxic secretion into plants and that the saliva of Miridae is so toxic it may cause changes in the tissue much more rapidly than could be produced by a virus. This rapidity in expression of damage approximates that which generally follows the application of hormones to plants and the similarity is of considerable interest.

SIMILARITY IN ENZYMIC ACTIVITY WHERE IT APPEARS INVOLVED.—The release of active hormones in plant tissues may have some relation with the activity of enzymes (Skoog *et al.*, 1940). There is also evidence that auxin affects respiration (Berger *et al.* 1946; Commoner & Thimann 1941). Although the specific action of auxin still remains to be illustrated, there are good indications that auxin release and action is exerted in connection with enzymes.

Numerous investigators have pointed out the presence of enzymic activity in connection with insect feeding upon plants. Cosens (1912) in considering the physiology of gall formation concludes that a larva secretes an enzyme which converts starch to sugar. Typical lesions caused by cotton flea hoppers were obtained by Painter (1930) following injection of diastase in plant tissue and froghopper injury to sugar cane has been shown (Hardy 1927) to increase the content of oxidizing enzymes. That certain leafhoppers secrete diastase and invertase is reported by Herford (1935), and that saliva of some mosquitoes contain an enzyme which produces a reaction in plant juices causing precipitation of its contents is described by Andrew (1921).

Little information is available, however, on the effect of either enzymatic activity, insect feeding, or plant auxin on the

growth and differentiation in plants. Studies of auxin activity in plants by Wildman (1942) show that proteolytic enzymes release auxin from the protein after enzymatic hydrolysis by tryptic extract, trypsin, and chymotrypsin. An effect on the plant protein resulting from insect feeding has been found by Smith (1933). He has shown that proteins and amino acids, as determined by color tests make up a major portion of the sheath material after certain insect feeding.

SUPPRESSION OF INSECT DAMAGE BY PLANT HORMONES.—That *Lygus* feeding causes bean and blossom drop before pods are set has been recorded by Shull (1933) and others (Allen & Fisher 1943). It is pointed out that many have failed to attribute such injury of bean plants to insects, but instead, principally to hot weather and poor cultural conditions. Fisher *et al.* (1946) successfully applied hormones to bean plants to prevent blossom and pod drop as was used in preventing pre-harvest drop of applies. In these studies the hormone, especially alpha naphthalene acetic acid prevented abscission caused by the feeding of the tarnished plant bug, *Lygus oblineatus* (Say). There has been no other instance insofar as it is known where substances have been used for counteracting or suppressing insect damage to plants.

According to Skoog[1] *et al.* 1946 an explanation of the above behavior may be proposed as follows. It is known that auxin inhibits leaf abscission, Laibach (1933). Possibly, therefore, the insect feeding stops the normal auxin supply to the region of the abscission layer causing it to form. The application of alpha naphthalene acetic acid would then restore the normal supply of hormone and prevent the abscission. The insect therefore may produce an auxin inactivator or interfere in some other way with the normal supply.

In the event that certain substances can be utilized for counteracting or suppressing insect damage, an approach to the study of the effect of the insects might be through the consideration of those instances where particular insects are associated with particular portions of the plant host. Consequently, the insect in which its habitat is related to such responses in plants from hormones which produce responses such as changes in rates of normal growth, abnormal proliferation, induction of rooting, flowering, and parthenocarpy, prevention of abscission layer formation and others would be an important area of study.

Closely related to such benefits by hormones which suppress insect damage is recent evidence that certain insecticides may act as a plant growth promoting substance. Allen & Chapman (1946) found a stimulation and suppression effect in some plants following treatments with DDT. Vegetables grown in the absence of insects showed that certain concentrations of DDT produced increased growth rates of the entire plants. The plants tested varied as to susceptibility of DDT and excessive applications caused shortening of internodes, production of adventitious buds and the development of a witches' broom, symptoms which were quite identical to that frequently caused by growth substances.

A knowledge of the fundamental basis of action of plant hormones and insect injury should prove very useful in their intelligent application in the future. It would be of considerable significance in our warfare against insects if chemicals of the future were available that would not only kill insects but tend to inhibit their expression of plant damage as well as to improve the quality of the plant host itself.

CONCLUSIONS.—Plant growth regulating substances may be a new tool in the hands of the entomologist in explaining the nature of toxin activity following insect feeding.

Such substances will in some instances produce growth changes in plants similar to that caused by insects. They show a close resemblance in enzymatic activity where it is involved and they will inhibit the development of abscission caused by *Lygus*. Certain insecticides, particularly DDT, may also possess a hormone-like effect.

A knowledge of the fundamental basis of action of plant hormones and insects should prove very useful in the future if chemicals become available that would possess insecticidal activity as well as properties for inducing growth changes in plants and would suppress certain insect damage.—7-20-47.

[1] Suggested to the writer by Folke K. Skoog, Dept. of Botany, University of Wisconsin.

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# The Effect of Field-Applied Insecticides on Beneficial Insects of Citrus in California

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These observations of the effect of insecticides used on citrus trees on beneficial insects under field conditions in California have been made at various times during the period 1907 to 1947. This period can be divided into three parts: (1) The period of intermittent treatment prior to the introduction of white oil sprays; (2) The period of white oil sprays and intensive treatments; (3) The period of the newer synthetic organic compounds.

At the beginning of this period, fumigation was the only insecticide application in general use and a very small proportion of the citrus orchards were treated annually. Many orchards, for several years at a time, received no insecticide application of any kind. Occasional orchards were sprayed with 3 to 5 per cent distillate or coal-oil, and a little later lime sulfur came into limited use for red spider.

This was a period when black scale, purple scale, red scale and yellow scale were the primary orchard pests, with citrus mealybug and red spider doing occasional damage. Black scale eggs were heavily attacked by *Scutellista cyanea* Motsch. The ladybird *Rhizobius ventralis* (Er.) also preyed heavily on the immature scale. *Aphytis chrysomphali* (Mercet) could be found actively at work in every orchard infested with red scale, in fact, not infrequently accomplishing very good commercial control. Neither purple scale nor yellow scale was attacked by important beneficial insects although *Rhizobius ventralis* (Er.), *Lindorus lophanthae* (Blaisd.), *Chilocorus bivulnerus* Muls. and *Scymnus* spp. were widely scattered throughout scale infested orchards and were general scale feeders. With the exception of a few orchards, the citrus mealybug was under natural control everywhere by predators, the dominant species being *Cryptolaemus montrouzieri* Muls., *Sympherobius barberi* Banks, *S. californicus* Banks, *Hyperaspis lateralis* Muls. and *Chrysopa californica* Coq., as well as a still undescribed species of *Chrysopa* which has always been confused with *C. californica* Coq. but whose immature stages and life history are very distinct. Red spider was usually under commercial control, primarily by the predators *Conwentzia hageni* (Banks), *Somatium oviformis* (Casey) and *Stethorus picipes* (Casey). There were many cases, in coastal areas, where spider infested orchards which were sprayed for control with lime sulfur showed only a temporary check of the pest because of reduction also of natural enemies, whereas unsprayed orchards adjacent cleaned up more quickly and more permanently through undisturbed biological control. For the same reason spider often increased rapidly soon after orchards were fumigated.

Taking the situation as a whole, the commercial insecticides used on citrus during this early period, which included HCN fumigation, distillate and coal-oil sprays and lime sulfur, had no important influence on the activity of parasites and predators from the period 1907 through the succeeding 10 or 15 years, except perhaps those of the red spider. It is well to emphasize that very few orchards were treated annually at that time, that the dosages used were light and that the work was less thorough than it is today. The highest fumigation dosages usually killed less than 50 per cent of the *Scutellista* larvae and pupae within the scale and *Rhizobius* beetles and larvae would be found on trees the day following treatment. Since the highest mortality from fumigation was of the immature scale stages and the lowest the mature scales and eggs, the combination of fumigation and beneficial insects was more effective than either alone. Even *Aphytis chrysomphali* (Mercet) could be commonly found in fumigated orchards and most ladybirds showed less than a 50 per cent kill. While fumigation and distillate sprays would cause a temporary check of the beneficial insects of the common citrus mealybug, invariably this was soon overcome and ultimately the mealybug was controlled by the natural enemies. In fact, not a few mealybug-infested orchards in which growers credited control to fumigation or

spraying actually were rid of the pest by beneficial insects.

With the introduction of the white oil sprays in the twenties by Luther and Volck, the developing resistance of certain citrus pests to particular insecticides, the introduction of double treatment of oil spray and fumigation, the increased power of spray equipment, the use of towers and greater volume and the general alertness of citrus growers to pest control so that few orchards escaped at least one treatment every year, there has resulted an effect on the parasites and predators in our citrus orchards which has for the most part been very destructive. Beneficial insects such as *Hyperaspis lateralis* Muls., which 30 years ago could be counted on a mealybug infested tree by the hundreds, has almost disappeared from citrus orchards. *Rodolia koebelei* (Olliff), once quite abundant in Ventura County, has disappeared completely. The steel-blue ladybird *Orcus chalybeus* (Boisd.), common for years throughout the citrus orchards of Santa Barbara County, is now seldom seen in orchard plantings since the two-spray program of white oil has been used. The brown lacewings *Sympherobius barberi* Banks and *S. californicus* Banks, whose cocoons invariably became very numerous in every mealybug infestation throughout southern California, may still be found in mealybug infestations but their effectiveness is seldom conspicuous. *Aphytis chrysomphali* (Mercet), formerly abundant in every red scale infested grove still persists but is usually abundant only in heavily infested trees which receive only sporadic treatments or are in semi-abandoned condition. *Scutellista* and *Rhizobius* are still found everywhere that black scale continues in commercial infestation but are in reduced numbers. It is exceptional to find the major spider predators, Conwentzia, Somatium and Stethorus, especially the first two, in anywhere near their former abundance, even in the most heavily infested grooves. The predators perhaps least affected by the present intensive treatments are *Chrysopa* spp., the aphid feeding Coccinellidae *Hippodamia* and *Coccinella*, and Syrphidae.

The commercial production and liberation of vast numbers of *Cryptolaemus* quite naturally has tended to suppress the building up of such native predators as *Hyperaspis*, *Sympherobius* and *Leucopis*. Two black scale parasites introduced by Professor Harry S. Smith, *Metaphycus lounsburyi* How. and *M. helvolus* Comp., have become universally established in the black scale areas and have for years assisted *Scutellista* to handle black scale everywhere except in some interior single-brooded areas. These three important insects persist in spite of oil spray and fumigation.

Of all our citrus pests the red spider has perhaps been the greatest enigma. Originally it was never damaging in the more interior areas, being a pest only in the coastal areas, with occasional increase in the intermediate districts. Where not disturbed by treatment it was usually under control by natural enemies, especially certain beneficial insects. Following the introduction of oil sprays into the intermediate areas, red spider increased to the status of an annual major pest and this same condition was later duplicated in the most interior orange areas of southern California. Today the interior areas suffer most heavily and persistently from red spider damage—the coastal orange areas the least. It is generally recognized that beneficial insects no longer exert an important influence on red spider control in the interior; influence at the coast is uncertain. What are all the factors involved? This would be a nice problem for a doctorate.

The commercial use of insecticides has not noticeably affected the population level of citrus thrips aside from the direct effect of control. No parasites of citrus thrips are known to occur and the four or five species of predaceous insects and spiders exert little control on the thrips population. An indirect effect by the insecticide in occasionally producing a flush of growth is sometimes favorable for increased development of thrips.

Citricola scale normally develops as an even single generation of scale. Under such conditions the several parasites, mainly *Metaphycus* spp. and *Coccophagus* spp., have only a limited season for effective parasitization since they attack mainly small stages of scale. *Metaphycus luteolus* Timb. may also attack adult citricola scale but seldom does under normal conditions because at the time scale reaches maturity, parasites are extremely scarce. If, however, this scale tends to de-

velop a second generation, resulting in various sizes of scale through the summer, as occurred in southern California in 1934 and in central California in 1946, parasites develop rapidly and attack scales of suitable size. In central California, this occurred in many groves heavily dusted with 2 per cent DDT in sulfur with as many as three or four applications of 100 pounds per acre. Neither the DDT nor the sulfur as used discouraged the parasites after 2 to 3 weeks following application over several thousand acres treated in 1946. But in spite of this unusually heavy build-up of parasites, particularly *Metaphycus luteolus* Timb., citricola scale still developed into the heaviest general infestation in over 20 years. The summer weather was very favorable to scale build-up. Obviously, the present complement of parasites and predators of citricola scale exercises little influence where the major scale population undergoes a single more or less even generation. Also, experience has shown that no particular detrimental effect of any of the commonly used insecticides against parasites and predators of citricola scale is found in the field.

Yellow scale is heavily parasitized in citrus groves by *Comperiella bifasciata* How. The application of various insecticides obviously reduces the parasite population at times. In central California it has been found necessary to treat for control of yellow scale without regard to the parasite. Parasitization may be relatively high at times but rarely high enough to afford control before serious damage has occurred. Although certain immature stages of *Comperiella* may survive cyanide fumigation, there is little opportunity for them to develop since the fumigation normally kills a high percentage of the yellow scale, their host. Sulfur dust has been reported to be inimical to parasite activity but there is little field evidence in support of this. Female *Comperiella* have been observed ovipositing in yellow scale covered with sulfur dust at an official temperature of 105° F. without apparent disturbance. There are some indications that DDT applications, by killing *Comperiella*, have favored yellow scale increase as yellow scale showed a heavy build-up in many DDT treated orchards in central California. Since DDT has been used but a single season, the evidence is not entirely clear. *Comperiella* has been more valuable in yellow scale control in southern California than in central California.

Soft brown scale normally is held in check in citrus groves by the parasites that affect citricola scale. In the case of soft brown scale, which has several generations within a season, there is overlapping of stages and scale of suitable size for parasite activity most of the time. In this case parasites are sufficient in themselves for commercial control. Infestations of soft brown scale usually develop only in the presence of ants, mainly the Argentine ant. In such cases artificial control has occasionally been resorted to. Heavy spray application of DDT, 15 pounds of 50 per cent wettable DDT per 100 gallons of water, has temporarily aggravated established infestations. But the use of insecticides, including DDT, has not created any more of a soft brown scale problem generally than otherwise would have occurred.

Treatments with arsenicals or DDT have at times resulted in heavy infestations of cottony cushion scale, *Icerya purchasi* Mask. The use of arsenicals many years ago on citrus, and now prohibited by law, was generally known to have frequently resulted in serious cottony cushion scale infestations by eliminating the vedalia, *Rodolia cardinalis* (Muls.). Recently, with the advent of commercial DDT treatments in citrus groves in the San Joaquin and Sacramento valleys for the control of citrus thrips and citricola scale, this problem has again arisen. As a result of but 1 year's commercial use, DDT applications have already been definitely restricted by the threat of further cottony cushion scale increase. Only a small percentage of the treated groves have developed a cottony cushion scale problem and these have been sprayed with DDT at least once and usually twice or more in the period of April through July. Neither spray applications during the remainder of the year nor dust applications at any time have as yet resulted in serious cottony cushion scale infestations.—7-20-47.

# Overwintering of Potato Flea Beetles in the Yakima Valley

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Flea beetles have caused severe loss to potato growers in the Northwest, chiefly because of the larval damage to potato tubers. In Washington the first severe damage occurred in 1925, when a flea beetle presumed to be the potato flea beetle, *Epitrix cucumeris* (Harris), was found in abundance. However, in 1944 Gentner described *E. tuberis* (tuber flea beetle) and concluded that published records of *E. cucumeris* in Washington, Oregon, Colorado, and western Nebraska refer to *E. tuberis* Gent.

The western potato flea beetle (*Epitrix subcrinita* (Lec.) has been present in Washington for many years and causes little damage to potato tubers.

The overwintering habits of potato flea beetles have been studied in several western States. In western Washington Webster *et al.* (1933) observed adults of the western potato flea beetle active in the field from April to October 21 and traced their movement from potato fields to grass, Douglas fir, and willows during September and October. In the same area Hanson (1933) observed adult tuber flea beetles hibernating in the soil of old potato fields, in debris about the fields, and to some extent in moss and on the bark of trees. In Colorado Daniels (1941) found that adults of the tuber flea beetle pass the winter in the soil at depths of 4 inches or more. In Nebraska Hill & Tate (1942) observed that large numbers of adult tuber flea beetles survived the winter in soil covered with old potato vines and other litter but that relatively few adults survived in bare soil of potato fields, in alfalfa fields, and in uncultivated areas.

In the fall of 1943 studies were begun at Yakima, Washington, to determine the overwintering habits of these potato flea beetles and to observe differences between the species which might have a bearing on the development of control measures. These studies dealt chiefly with the nature of the protective cover, or medium, used by flea beetles for overwintering and the amount of the protective cover essential for high survival.

Methods.—Adults of the two species of potato flea beetles were swept from potato foliage in September, counted, and placed in outdoor cages containing different kinds and amounts of overwintering materials. The proportions of the two species placed in each cage were determined from samples of beetles which were killed and examined as the cages were stocked.

The cages were made of wood and consisted of two parts, a bottom or medium box and a top or superstructure. Each part was 12 inches square. The medium box was 3, 6, or 12 inches deep, and the bottom was covered with 30-mesh wire screen. The superstructure was 6 inches high, and the top was covered with cheesecloth except for a wooden ring and tight-fitting cork placed in one corner. The medium boxes were filled with a mixture of grass and tree leaves or with soil tamped to a moderate firmness. Boxes containing vegetative litter were left above ground, but those containing soil were buried in the ground with the tops at soil level. Narrow strips of felt were placed between the two parts of the cages, which were then held together by wire bands.

In the spring emergence traps were installed in place of the super structures. The emergence traps were of wood, and two sides sloped to a rooflike peak on which a fruit-jar collection trap (Getzendaner & Davis 1947) was installed. Flea beetles were removed three times a week and identified.

Soil and Vegetative Litter as Overwintering Media.—During the week ending September 27, 1943, approximately 240 tuber flea beetles and 760 western potato flea beetles were placed in each of 5 replicate cages containing 3, 6, and 12 inches of soil or vegetative litter. After the flea beetles had become inactive, the superstructures were removed to permit rain and snow to penetrate the media. The unused food remnants also were removed from the soil media. Emergence traps were installed on March 8, 1944.

[1] In cooperation with the Washington Agricultural Experiment Station.

The survival of the two species of flea beetles in each type of medium is shown in table 1. An analysis of variance of the results of the five replicates of each treatment showed no significant difference in recovery between the three depths of each overwintering medium. However, the survival of the two species of flea beetles was quite different in the two overwintering media. In the cages containing vegetative litter the average survival of the western potato flea beetle was 30.5 per cent, and that of the tuber flea beetle 13.2 per cent. In cages containing soil the survival of the western potato flea beetle was 0.2 per cent, and of the tuber flea beetle 40.8 per cent.

**Table 1.—Survival of tuber flea beetles and western potato flea beetles in overwintering cages containing either vetetative litter or soil, 1943–1944.**

| Overwintering Medium | Depth of Medium | Adult Survival | |
|---|---|---|---|
| | | Tuber Flea Beetle | Western Potato Flea Beetle |
| | *Inches* | *Per Cent* | *Per Cent* |
| Vegetative litter | 12 | 6.6 | 30.3 |
| | 6 | 15.8 | 24.5 |
| | 3 | 17.3 | 36.6 |
| Soil | 12 | 46.9 | 0.3 |
| | 6 | 29.8 | 0.1 |
| | 3 | 45.7 | 0.1 |

At the time the experiment was planned it was presumed that the flea beetles entering overwintering media remained immobile until spring. This appears to be true for the tuber flea beetle but not for the western potato flea beetle. During the winter of 1943–1944 adults of the western potato flea beetle were observed crawling about on days when the temperature rose to about 50° F. Such rapid response to short periods of abnormal winter temperature shows that the adults of the western potato flea beetle do not actually hibernate.

Since some western potato flea beetles may have left the open medium boxes during the winter of 1943–1944, a similar test was begun in the fall of 1944, but the medium boxes were kept covered until emergence traps were installed in the spring. In addition to the soil and the vegetative-litter media a combination of soil with a covering of litter was tested. Two thousand flea beetles were placed in each cage. As in the earlier tests, there were five replicates of the soil medium, five of the vegetative-litter medium, and ten of the soil-litter combination. However, on December 8 the frozen mass of litter was carefully removed from five cages containing the combination of soil and liter and placed in empty medium boxes above ground. Emergence of flea beetles was recorded from both the soil and the litter portions of the original combination.

In 1945 the emergence traps were exchanged for the superstructures on Februrary 10, and adults of the western potato flea beetle were collected immediately. The emergence reached the peak on April 16 and ended on May 28. Emergence of the tuber flea beetle began on April 28, reached the peak on May 28, and ended on September 4. The recovery is shown in table 2.

The results of the 2 years' tests show that the western potato flea beetle and the tuber flea beetle have different overwintering habits. The tests in which the litter portion of the soil-litter medium was removed during the winter showed that 98.3 per cent of the surviving adults of the western potato flea beetle emerged from the litter, and 97.6 per cent of the tuber flea beetles emerged from the soil. In other treatments survival of the western potato flea beetle was high in litter without soil, and low in soil without

**Table 2.—Survival of tuber flea beetles and western potato flea beetles in overwintering cages containing both soil and vegetative litter, 1944–1945.**

| Overwintering Media | Adult Survival | |
|---|---|---|
| | Tuber Flea Beetle | Western Potato Flea Beetle |
| | *Per Cent* | *Per Cent* |
| 12 inches of soil and a trace of litter | 70.5 | 27.9 |
| 6 inches of soil and 6 inches of litter, not separated | 39.1 | 39.7 |
| 6 inches of soil and 6 inches of litter: | | |
| From soil only | 57.7 | 0.8 |
| From litter only | 1.4 | 44.0 |
| 12 inches of vegetative litter | 11.5 | 29.2 |

litter. Conversely, survival of the tuber flea beetle was low in litter without soil, and high in soil without litter. The 1944 tests, however, indicated that a light covering of litter on the soil, as simulated by unused food-plant remnants, may increase survival of the tuber flea beetle.

These studies indicate that the destruction of plant remnants in and around potato fields may be helpful in the control of the western potato flea beetle but would be of no value in the control of the tuber flea beetle.

VERTICLE DISTRIBUTION OF FLEA BEETLES IN SOIL.—The normal vertical distribution of the two species of flea beetles within overwintering media was determined by confining 3000 beetles above a deep column of soil in the fall and determining the location of the living beetles within the soil column during the winter.

In the fall of 1944 a wooden box 6 by 6 by 30 inches was filled with soil and buried in an upright position in the ground with the top flush with the ground surface. The flea beetles were confined in a superstructure placed over the soil column. On February 8, 1945, the box was removed and brought into the laboratory, where one side was removed to expose the soil. The unused food-plant remnants and the flea beetles observed unburied on the soil column were placed in a glass emergence jar. The soil was then sliced off in 1-inch layers from top to bottom, and each layer was placed in a glass jar labeled as to position within the column. Flea beetles that became active in the jars during a 2-month period were removed, identified, and counted.

From the time the beetles were placed over the 30-inch column of soil in the fall to February 8, mortality of the western potato flea beetle was 41.7 per cent and of the tuber flea beetle 57.5 per cent. Of the western potato flea beetles recovered alive, 97 per cent were found with the food-plant remnants, but no live tuber flea beetles were found there. The number of tuber flea beetles that emerged from the layers of soil increased irregularly from 2 at the 1-inch level to 99 at the 9-inch level and then decreased to 1 at the 21-inch level

These data show that the tuber flea beetle may survive at shallow depths. It is possible, however, that mortality was greatest at the shallow depths and that the distribution of survivors in the soil may not be indicative of the actual vertical distribution of beetles entering the soil.

EFFECT OF BURIAL ON OVERWINTERING FLEA BEETLES.—To test the influence of the depth of overwintering media on the survival of the two species of flea beetles, 10 boxes of various depths, each containing 6 inches of soil, were stocked with known numbers of flea beetles the last week of September 1944. The beetles were fed until killing frost occurred. The boxes were 12 inches square, and two each were 6, 12, 18, 24, and 30 inches deep.

On November 11 sufficient soil was added to fill the boxes. Thus there were two replicates of 6 inches of soil containing a natural vertical distribution of flea beetles, and two replicates each of 6 inches of soil containing flea beetles and additional layers of 6, 12, 18, or 24 inches of soil. On February 10, 1945, the cage superstructures were replaced by emergence traps, and three times a week the flea beetles that emerged were collected, counted, and identified. The emergence data are presented in table 3.

Two days after the emergence traps had been installed adults of the western potato flea beetle were collected from all cages. Apparently the adults had gradually worked up through the various depths of soil during the winter. Significantly greater numbers were recovered from the boxes in which no soil covering had been added.

**Table 3.—Adult potato flea beetles emerging from 6-inch layers of soil buried at different depths, 1945.**

| Depth Buried (Inches) | Western Potato Flea Beetles (2172 Introduced) | Tuber Flea Beetles (1828 Introduced) |
|---|---|---|
| 0 | 664 | 950 |
| 6 | 273 | 1076 |
| 12 | 428 | 1214 |
| 18 | 239 | 808 |
| 24 | 288 | 816 |

Survival of the tuber flea beetles was highest in the boxes in which the original 6 inches of soil was covered with an additional 12 inches of soil. The distribution of survivors in boxes with 6-inch layers

of soil follows the same general trend as that in the box containing 30 inches of soil. Although no adults were observed to have penetrated deeper than 21 inches in the 1943–1944 experiment, many beetles that had been buried beneath 24 inches of soil during the 1944–1945 experiment were able to reach the surface.

The effect of burial was further tested on December 5, 1945, when three rows of undug potatoes were turned under to a depth of 12 inches with a tractor plow. The emergence of overwintering flea beetles was determined by trapping the insects in cages that covered 3.5 square feet. Twelve pairs of cages were used, one of each pair being on the plowed land and the other within 4 feet on unplowed land. A total of 146 tuber flea beetles and 82 western potato flea beetles emerged from the plowed areas and 174 tuber flea beetles and 45 western potato flea beetles from the unplowed areas. The plowing was of no value in reducing flea beetle emergence.

SUMMARY.—The western potato flea beetle, *Epitrix subcrinita* (Lec.) and the tuber flea beetle, *E. tuberis* Gent. attack potatoes in the Yakima Valley, Washington, but have different overwintering habits, which preclude the development of a uniform method of cultural or insecticidal control during the winter.

Cages used in determining the overwintering habits of the two species of flea beetles consisted of wooden boxes of various depths in which measured amounts of soil, vegetative litter, or combinations of the two, were placed, and known numbers of flea beetles were introduced in the fall. The suitability of the different media was determined from the number of beetles recovered in the spring.

Differences in recovery of the two species showed that vegetative litter was essential for high survival of the western potato flea beetle, and soil for the tuber flea beetle. Differences in the numbers of each species recovered from 3, 6, or 12 inches of litter or soil were not of mathematical significance. In cages containing vegetative litter the average survival of the western potato flea beetle was 30.5 per cent and of the tuber flea beetle 13.2 per cent. In cages containing soil the survival of the western potato flea beetle was 0.2 per cent and of the tuber flea beetle 40.8 per cent. These figures indicate that the destruction of plant remnants in and around potato fields may be helpful in the control of the western potato flea beetle but not in the control of the tuber flea beetle.

In a test to determine the vertical distribution of living flea beetles confined in a 30-inch column of soil covered lightly with vegetative litter, 97 per cent of the western potato flea beetles were found in the top inch of soil and litter, and the maximum number of tuber flea beetles were at the 9-inch level, although some were found in each inch layer of soil above this level. The maximum depth of penetration was 21 inches.

In a test on the effect of burial of flea beetles in the soil, both species emerged in considerable numbers from a 6-inch layer of soil that had been buried under 24 inches of soil. In preliminary tests plowing to bury the overwintering flea beetles was of no value in reducing winter survival of either species.

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# Quantity of Food Consumed by Mormon Crickets

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The work reported in this paper was undertaken to determine the total amount of food consumed by the individual Mormon cricket (*Anabrus simplex* Hald.) during the nymphal and early adult periods and the average daily consumption by the cricket during each instar.

METHOD.—The method used was devised by Parker (1930) in similar studies of *Melanoplus mexicanus mexicanus* (Sauss.). The grasshoppers were fed on small disks cut from fresh leaves of wandering-jew, *Tradescantia*. The disks were supplied in slight excess of the daily need, and any food remaining in the tubes after 24 hours was carefully removed, dried, and weighed. A 50-disk sample was retained from each day's food supply, and the average dry weight of a single disk was determined. The quantity of food offered each day was determined by multiplying the number of disks fed by the average dry weight of a single disk.

Two series of tests were conducted with Mormon crickets, one in the laboratory during the winter of 1936 and the other outdoors during the spring and early summer of 1941.

The 1936 tests were conducted with laboratory-reared crickets obtained from eggs collected in the field the preceding fall. The test insects were caged singly in glass tubes, 8 inches long and 1.5 inches in diameter, closed at both ends by wire screen or gauze. They were held at constant temperatures of 77° and 86° F. and a constant relative humidity of 30 per cent. The high mortality necessitated frequent replacements from a stock supply of crickets of approximately the same age. Without replacements it would have been impossible to carry the tests through the full number of instars. After unsatisfactory trials had been made with wandering-jew as the test food, all crickets were fed on disks cut from the outside leaves of lettuce. These disks were 1.6 cm. in diameter, and after drying weighed on an average 4.47 mg. each. All excess food removed from the tubes was dried 24 hours at room temperature before being weighed. All weighings were made on an analytical balance accurate to 0.1 mg.

In 1941, because of the possibly abnormal results from the use of laboratory-reared crickets, the experiments were repeated with crickets brought fresh from the field. Mormon crickets are extremely difficult to rear under laboratory conditions. Not only is the mortality high, but the individuals that survive are often malformed, small, and lacking ing in vigor. These tests were conducted at outdoor temperatures, in order to simulate natural field conditions.

First-instar crickets were hatched from eggs collected in the field. All others were brought in from their natural environment and allowed to molt once before being used. As tests with crickets of one instar were completed, those individuals were discarded and fresh ones from the field substituted. All test crickets were held singly in small wire-screen cages

Disks cut from fresh alfalfa leaves were used as the test food. These disks were 1 cm. in diameter and weighed approximately 3 mg. after drying 24 hours at 205° F. All uneaten food removed from the cages was likewise dried 24 hours at the same temperature before being weighed.

RESULTS.—The time spent in each instar by individual crickets varied greatly. This variation was more pronounced in the 1941 tests, where all crickets were held at outdoor temperatures, than in the 1936 tests under uniform temperature and moisture conditions. The average time spent in each instar was considerably less in 1936 tests than in 1941. This was to be expected because the average outdoor temperature was much lower than the constant temperature maintained in the laboratory. The premolt lay-off in feeding, observed first in 1936, was more apparent in 1941, when the crickets ceased feeding about 3 days before molting. This is shown graphically in figure 1.

A total of 123 days were required to complete the cycle from hatching to adult under outdoor conditions of the 1941 tests. The same cycle was completed under constant temperatures in 1936 in

[1] Resigned May 6, 1943.

70 days. Under field conditions the total period from hatching to adult is probably nearer 90 days.

As shown in table 1, the average total amounts of food consumed per cricket in the two tests were similar through the fourth instar. On the other hand, the average daily consumption was much higher in 1936 during the first four stages. Beginning with the fifth instar the daily consumption in 1941 increased and when the seventh instar was reached showed a marked gain over that in 1936. A corresponding gain is evident in the total amount consumed during the seventh instar. Crickets that had developed in the field were noticeably larger after they had

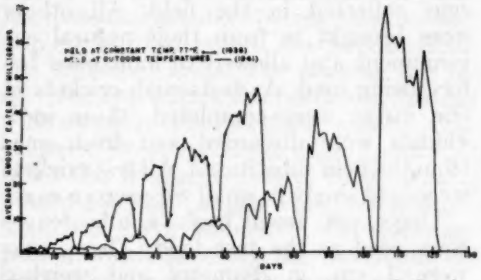

FIG. 1.—Average amount of food eaten each day by selected individual Mormon crickets having the same number of days per instar. The prominent depressions in the graphs indicate the terminations of instars.

reached the fifth instar than those that had been reared in the laboratory. The field-reared crickets were also more vigorous than those reared under artificial conditions. Even though they required more time in every instar and ate less food per day during the first five instars, the sixth-instar crickets in 1941 ate as much per day and the seventh-instar crickets considerably more than did crickets in the same instar in 1936.

As shown in figure 2, the average daily amount eaten per individual by 20 adult crickets was considerably less in 1941 than in 1936 apparently because of the lower temperatures at which the 1941 experiments were conducted. There is also greater day-to-day variation in the amounts eaten by the adult crickets in 1941. On the few warm days during the 1941 tests, however, slightly higher individual feedings were recorded than in 1936. In 1941 the largest amount eaten

**Table 1.—Average amounts of food eaten by individual Mormon crickets in the various stages of development in laboratory (1936) and outdoors (1941). All weights shown on a dry basis.**

| Instar | Year | Number of individuals | Average Days in Instar | Milligrams of Food Eaten per Cricket | |
|---|---|---|---|---|---|
| | | | | Total | Average daily |
| 1 | 1936 | 63 | 7.5 | 8.03± 0.67 | 1.07 |
| | 1941 | 40 | 14.9 | 11.03± .43 | .74 |
| 2 | 1936 | 53 | 7.6 | 24.36± 1.19 | 3.20 |
| | 1941 | 61 | 15.4 | 22.46± .58 | 1.46 |
| 3 | 1936 | 55 | 8.3 | 50.78± 2.22 | 6.12 |
| | 1941 | 20 | 17.3 | 51.57± 2.20 | 2.98 |
| 4 | 1936 | 51 | 8.6 | 98.46± 4.16 | 11.45 |
| | 1941 | 17 | 18.2 | 110.42± 5.15 | 6.07 |
| 5 | 1936 | 48 | 9.6 | 173.30± 6.13 | 18.05 |
| | 1941 | 24 | 17.5 | 234.35±15.09 | 13.39 |
| 6 | 1936 | 51 | 13.5 | 329.06±16.08 | 24.37 |
| | 1941 | 20 | 20.6 | 485.30±25.16 | 23.56 |
| 7 | 1936 | 33 | 14.3 | 489.05±22.05 | 34.20 |
| | 1941 | 18 | 19.1 | 842.31±20.30 | 44.10 |
| Totals | 1936 | 354 | 69.4 | 1173.04 | |
| | 1941 | 200 | 123.0 | 1757.44 | |
| Adult | 1936 | 20 | 20 | 2017.20 | 100.9 |
| | 1941 | 20 | 20 | 1760.49 | 88.0 |

in 1 day by any individual was 177.7 mg., whereas in 1936 the largest was 170.2 mg.

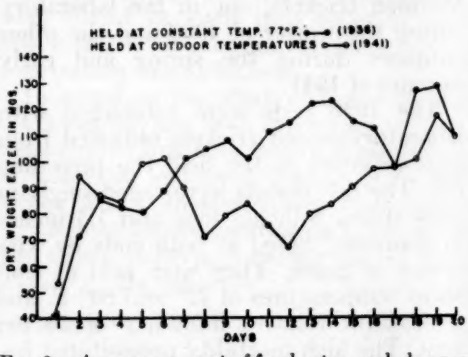


FIG. 2.—Average amount of food eaten each day per individual by 20 adult crickets.

COMPARISON OF THE QUANTITIES OF VEGETATION EATEN BY MORMON CRICKETS AND LIVESTOCK.—In the 1941 tests the total amount of food necessary to carry a single Mormon cricket through the entire nymphal period and 20 days of adult life was 3518 mg. On this basis a band of crickets covering 640 acres at the rate of 10 crickets per square yard—and bands of this extent and intensity are not uncommon—would consume 120 tons (dry weight) of vegetation in approximately 4 months. They would

probably eat considerably more than that in an entire season, since the adults normally live much longer than 20 days. If the band remained stationary, there would not be enough edible vegetation on any of the western ranges to support it. Mormon crickets migrate almost continuously during their entire lifetime, and the damage is therefore distributed over a much larger area than that actually occupied by the individual bands. In years of heavy infestations, however, they cause serious and extensive losses of range forage.

According to textbooks on feeding of livestock, the minimum requirement for maintaining a mature 1000-pound cow is 16 pounds of hay per day. Range authorities state that a mature animal will eat 25 pounds (dry weight) daily if larger quantities are available. An intermediate figure of 20 pounds would therefore seem to be a reasonable one to use as a basis for comparing the amount of forage eaten by livestock with that eaten by Mormon crickets, and determining their possible effects on the range.

Without overgrazing, the average range requirement for a mature animal in Nevada is 7 acres a month for a 9-month grazing period. A total of 10 head may therefore be grazed on each section of land. If each animal eats an average of 20 pounds of forage each day, the total daily consumption will be 200 pounds. During the 9-month grazing period a total of 27 tons would be removed from each section if the range were stocked to capacity. As has already been shown, about 4.4 times this amount, or 120 tons, would be eaten in a 4-month period by a band of crickets covering a section of land with a population of 10 per square yard. Such a band would thus pasture 4.4 sections to capacity during the season and consume the forage needed for 44 head of cattle.

The following figures, based on the 1941 records, show the numbers of crickets per square yard in all stages that would consume 200 pounds of vegetation per day on a section of land:

| INSTAR | NUMBER | INSTAR | NUMBER |
|---|---|---|---|
| First | 39.6 | Fifth | 2.2 |
| Second | 20.1 | Sixth | 1.1 |
| Third | 9.8 | Seventh | .6 |
| Fourth | 4.8 | Adult | .3 |

TYPES OF VEGETATION EATEN BY MORMON CRICKETS AND LIVESTOCK.—According to R. B. Swain, of the Bureau of Entomology and Plant Quarantine (unpublished reports), the 15 plants listed in table 2 constitute the major portion of the plant coverage of northern Nevada ranges. This information is based on the frequency of occurrence and the average composition in forty-five 100-square-foot plots and 15 transects examined by him in 1938 and 1939. The table shows how many of the total number of samples contained each species and the percentage contributed by each species to the total vegetation in the samples in which it was present. Other species which averaged more than 5 per cent composition but occurred less than 5 times in the 60 observations were *Stipa thurberiana*, *Carex*, *Stipa comata*, *Symphoricarpos oreophilus*, *Melica bulbosa*, and *Oryzopsis webberi*.

Only the first 10 plants listed in table 2 are valuable forage plants. These 10 plants are also among the ones which sustain the most damage from Mormon crickets. Together with sagebrush, *Artemisia*, and rabbitbrush *Chrysothamnus*, they constitute the main part of the vegetative cover on the ranges of northern Nevada. Although sagebrush and rabbitbrush constitute a large proportion of the plant cover, they are not eaten readily by crickets or livestock. There is, then, direct competition between crickets and livestock for the available forage during outbreak years. When such competition occurs on range that is already stocked to capacity, the results may be serious. In 1939 over 2 million acres of range land in

**Table 2.—Average composition of vegetation in 60 samples of northern Nevada range and per cent eaten by crickets.**

| PLANT | NUMBER OF TIMES RECORDED | AVERAGE PER CENT OF TOTAL VEGETATION IN SAMPLES | PER CENT EATEN BY CRICKETS |
|---|---|---|---|
| *Bromus tectorum* | 31 | 45 | 34 |
| *Lupinus caudatus* | 17 | 5 | 29 |
| *Poa* sp. | 10 | 13 | 27 |
| *Balsamorhiza sagittata* | 18 | 14 | 26 |
| *Erodium* sp. | 5 | 31 | 22 |
| *Sitanion hystrix* | 14 | 12 | 19 |
| *Poa secunda* | 25 | 22 | 12 |
| *Agropyron spicatum* | 27 | 12 | 11 |
| *Elymus condensatus* | 23 | 5 | 11 |
| *Phlox* sp. | 9 | 16 | 7 |
| *Festuca idahoensis* | 19 | 14 | 6 |
| *Wyethia* sp. | 5 | 4 | 5 |
| *Chrysothamnus* sp. | 30 | 8 | 1 |
| *Artemisia tridentata* | 40 | 20 | 1 |
| *Eriogonum* sp. | 10 | 4 | 0 |

Nevada were reported to be damaged by Mormon crickets. Much of this damage was slight, but many ranchers were forced to seek new range in uninfested areas. Fortunately this outbreak has been brought under complete control.

The situation in Nevada has been used as an example, because most of Swain's work on damage to range plants was done there, and also because the cricket outbreak of 1935 to 44 in that state was the most extensive and severe of any on record. However, the foregoing conclusions would apply to range lands in any other state where the northern desert-shrub type of vegetation prevails.

In the grassland types of range in Montana, Wyoming, and eastern Idaho damage to forage has been relatively unimportant even during years of extremely heavy cricket outbreaks. On the better ranges of Montana the average requirement for each mature animal is about 4 acres per month. On this basis 20 head per section could be grazed for an 8-month period without overgrazing. If each animal consumed 20 pounds a day, the total amount would be 48 tons. Theoretically, then, 640 acres of crickets at 10 per square yard would consume all available vegetation from 2.5 sections during their seasonal development. This in itself would be a serious loss in years of widespread infestation. The reason why such losses have never been reported lies in the composition of the range vegetation. In Montana the dominant grasses in areas where cricket outbreaks have occurred are wheat grasses, festucas, and needle-and-thread. Swain and other observers have reported little or no damage to any of these. Apparently crickets are able to thrive on the annuals and finer grasses, which are usually present in sufficient numbers and which are eaten in preference to the more valuable ones.

Although Mormon crickets are essentially range insects, they do invade cultivated crops in years of serious outbreaks. Wheat and other small grains usually suffer the greatest damage, but alfalfa ranks a close second. On the basis of the 1941 figures listed in table 1, an adult Mormon cricket is capable of consuming 88 mg. of food (dry weight) each day. An acre of crickets, at 1 per square yard, would be capable consuming of 426 grams, or approximately 1 pound, per day. Crickets in an alfalfa field confine their feeding to the leaves, which constitute about 40 per cent of the dry weight of the plant. The average yield of alfalfa hay on Montana dry land is about 1 ton per acre per cutting. If 800 pounds of leaves were eaten from 1 acre of alfalfa, the remaining 1200 pounds of stems would be practically useless as hay. Thus a population of 25 adult crickets per square yard over an acre could effectively destroy 1 ton of alfalfa hay in 32 days.

SUMMARY.—Studies on the quantity of food consumed by the Mormon cricket, *Anabrus simplex* Hald., were conducted during the winter of 1936 and again during the spring and summer of 1941. Based on the 1941 tests in which alfalfa leaves were used as the test food, a single cricket requires 3518 mg. to carry it from hatching through 20 days of the adult stage, a period of about 4 months. On this basis a band of crickets covering a section of land at a density of 10 per square yard would consume 120 tons of forage (dry weight) or the quantity available on 4.4 sections of northern Nevada range land if pastured to capacity, and also the quantity estimated to be required for the adequate pasturage of 44 head of cattle for 9 months. A population as low as 0.3 adult crickets per square yard over a section of range land and would eat as much as 10 head of mature cattle. Furthermore, 1 acre of adult crickets at 25 per square yard could ruin 1 ton of alfalfa hay in 32 days.

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# Dispersion of Fumigants Through Soil[1]

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Soil fumigation has, in the past, been limited to relatively small scale operations mainly due to economic factors which restricted its use to crops of high value per unit area. With the advent of D-D mixture, a low cost material, new interest in the field has been aroused and reconsideration of certain elements of the general problem has become necessary, among them being the movement of fumigant vapors through soil masses. Standard, well-known, analytical methods are in existence for many fumigants. None are known for D-D mixture which, while described as a mixture of 1,2 dichloropropane and two isomers of 1,3 dichloropropene (Carter 1943, 1945) contains in its commercial form, trichlorides and other higher boiling point fractions which precludes any common analytical method being used which would suffice to estimate them as a whole. Furthermore, even standard chemical methods require samples of considerable volume which, if drawn at intervals from the soil mass would interfere with the normal diffusion producing unreliable results.

Theoretically there are methods which might be used in some modified form to obtain continuous quantitative estimates of fumigant vapor movement through soil. These would include the use of absorption spectra or the principle of the change of thermal conductivity of a gaseous medium with the change in concentration of organic vapors therein. These methods, albeit capable of exceeding accuracy, require complicated apparatus both unwieldy and expensive and hence not adequately serving the needs of the present problem.

A biological assay method was devised to indicate the presence of fumigant vapors as well as giving a rough quantitative measure of the concentration of gas. The rice weevil, *Sitophilus oryza* L., has long been a standard test animal for comparison of toxic properties of fumigants and has served admirably due to its unusual sensitivity to low gaseous concentrations. Furthermore, its reaction to gas is little, if any, affected by atmospheric humidity nor does it require the presence of food materials during the observation period. It can be cultured in enormous quantities in any of a variety of whole grains such as rice, wheat, milo maize, etc., and can be separated and handled with ease without injury by simple mechanical suction pipettes. Its sensitivity to different fumigants has been so sharply defined that it has been possible to detect the presence of deviants in the components of D-D mixture which might otherwise only be detected through tedious fractionation and spectrographic analyses. A definite relation exists between the percentage mortality of the rice weevil exposure time and vapor concentration (Schmidt 1945). Hence if mortality percentage and exposure time are known, the concentration of gas may readily be derived with considerable accuracy. This method has been used successfully in detecting and estimating the movement of D-D mixture and chloropicrin through soil.

LITERATURE SUMMARY.—Most of the literature concerning the movement of fumigant vapors through soil pertains to practical aspects of the spacing of injections and the time required to elapse between injection and planting. Fleming and Baker (5) using larvae of *Popilia japonica* Newman, measured the diffusion of carbon bisulfide and found that the vapors did not diffuse uniformly in all directions but tended to move downward and laterally from the point of injection forming a cone-shaped region whose apex is close to the point of injection. At the end of 48 hours the carbon bisulfide had diffused in insecticidal quantities within a horizontal radius of 15 inches from the injection hole to a depth of 24 inches. Higgins & Pollard (1937) present limited quantitative observations on the movement of carbon bisulfide. They conclude that depth concentration in soil fumigated with carbon bisulfide is characterized by a high concentration in the zone of injection and immediately below it, a rapid decrease in concentration as the surface is approached, a slower decrease with depth below the zone of injection, a time-

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concentration curve for each layer rising sharply to a maximum concentration followed by a slower decline to a low level. Variations in depth of injection raise or lower the zone of high concentration. Increased dosage increases the persistence without causing changes in distribution or concentration maxima. Loss of fumigant is largely via the soil surface.

Because of its newness, nothing at all

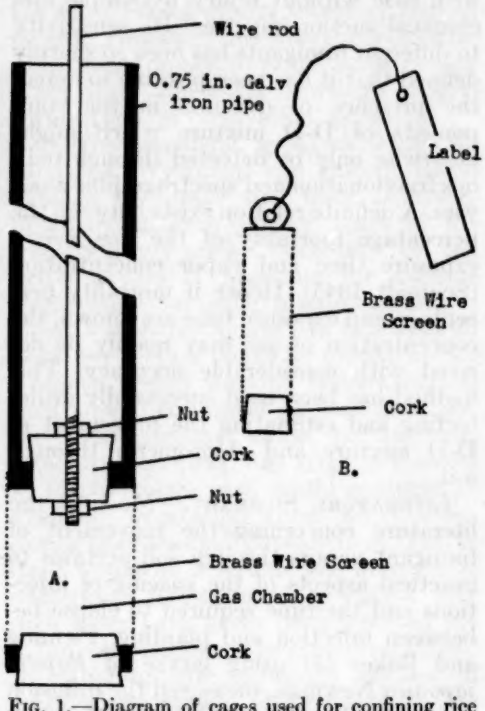


FIG. 1.—Diagram of cages used for confining rice weevils in the soil. A. Outer cage imbedded in the soil to the desired depth. B. Inner cage containing rice weevils which was inserted in the gas chamber of cage A.

was known previously concerning the diffusion of D-D mixture through soil. Mention is made of the low dispersion power in a bulletin published by the Shell Chemical Corporation (Anon. 1944). It is stated that the maximum acceptable spacing for field fumigation is 18 inches since the effective range of the vapors is not over 10 inches.

Taylor (1939) in a theoretical consideration of spacing of injection points for volatile fumigants sets up certain hypotheses for most efficient distribution of the vapors. This is based on the experimental determination of the range of

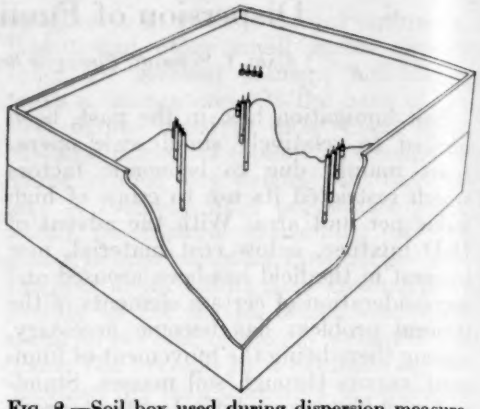

FIG. 2.—Soil box used during dispersion measurements showing the distribution of the cages used for confining the rice weevils.

satisfactory controls for specific organisms.

*Experimental Apparatus and Method.*—Gas concentrations were determined *in situ* by the use of soil cages constructed of galvanized iron pipe with bronze wire screen according to figure 1. These cages made it possible to place subsidiary bronze cages containing 40 rice weevils at varying lateral distances from the injection point and at various depths in the soil. The weevils were exposed in the soil for 5 hours, removed, and then replaced with others. Weevils were held for 24 hours after exposure to overcome anesthesia effects after which mortality was determined. In order to overcome possible interference effects of the cages in the soil they were placed so that each lateral group was 120 degrees from its neighboring group around a common axis centered

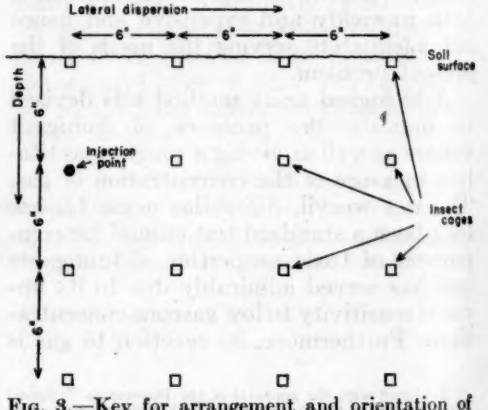


FIG. 3.—Key for arrangement and orientation of graphs in Figs. 4 to 11.

by the point of injection (Fig. 2). The soil mass, thus, for each lateral group was of the same composite but different for each group of lateral cages. In presenting the data, these discrete observations are assembled as though they were a single plane for clarity of presentation (Fig. 3).

The soil for the experiments was typical lateritic pineapple soil from Wahiawa, Oahu, which was placed in a wooden box 24 inches deep and 48 inches square after having been composited and adjusted to taken at depths from bands of 1 to 3 inches, 6 to 8 inches, 12 to 14 inches and 18 to 20 inches respectively. No readings were taken at the actual injection point. The fumigant liquid was introduced into the soil mass to a depth of 6 inches (unless otherwise specified) by means of a small glass tube which was withdrawn when completely drained of its liquid. Temperature fluctuations reflected those of the atmosphere with diurnal changes definitely influencing the mortality near the

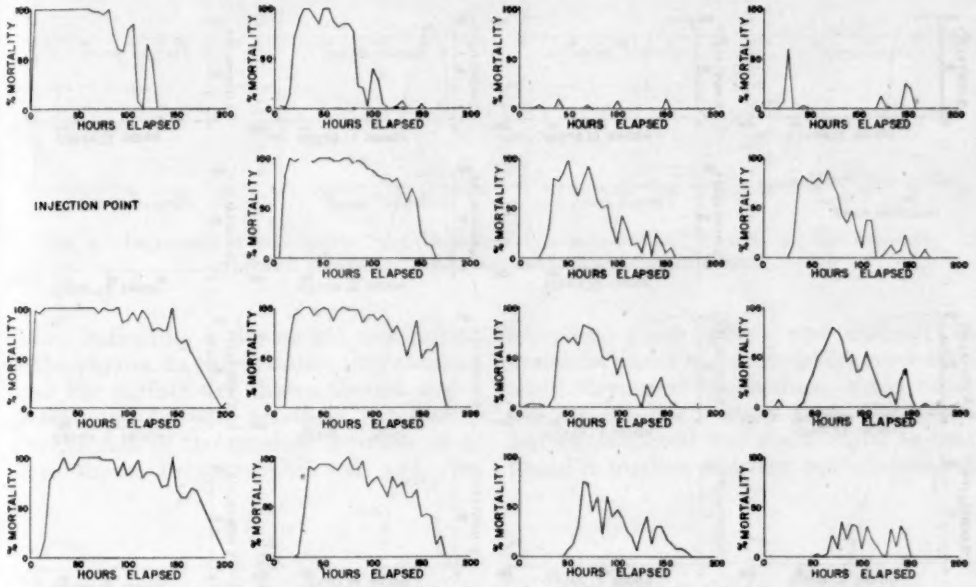


FIG. 4.—Dispersion of chloropicrin from injection point in dry soil, circa 10–12 per cent moisture, expressed in terms of percentage mortality of the rice weevil.

moisture content. Moisture contents given represent an average of readings made from samples taken at each location where readings on gas concentration were to be made. Moisture changes due to drying occurred as each experiment proceeded, being most pronounced at the surface and least at greatest depth. In the case of the highest moisture content it was necessary to sprinkle the surface two or three times daily in order to prevent gas leakage due to the soil cracking away from the pipe cages. The cages at which records were to be made were placed above the point of injection and at lateral distances of 6, 12 and 18 inches from the injection axis and at depths of 1, 6, 12 and 18 inches. Since any cage is possessed of dimensions, the readings were actually surface while causing merely minor variations at greater depth. Other known errors are those occurring due to the tendency of gas vapors to rise on coming in contact with a solid surface such as the pipes of which the observation cages were made. Whatever the scope of this error, it was not sufficient to alter the trends of the gas movement perceptibly or significantly.

The dosage of material applied cannot be expressed in terms of pounds per acre since acre dosages, as fumigants are actually applied, are dependent on the pattern of application of unit dosages. However, if the pattern was that of current pineapple culture practices it would be the equivalent of 1,000 pounds per acre, though, if placed on one foot quadrats it

would be greatly in excess of this amount. High dosages were used in order to magnify the results. Previous pilot experiments had indicated that increased dosage had little influence on rate or direction of vapor movement within the limits of the concentrations here employed. This has also been noted with carbon bisulfide by Higgins and Pollard (1937).

THE DISPERSION OF CHLOROPICRIN THROUGH SOIL.—1. *Soil of low moisture.* The movement of chloropicrin vapor in soil of circa 10–12 per cent moisture is shown in figure 4. High concentrations of vapor are seen to exist 6 inches above and below the injection point during the first five-hour interval after treatment while lateral dispersal was slower and not detectable until 10 hours while 25 hours were required for the vapor to reach 12 inches. The pattern of dispersal shows a tendency for the gas to move downwards and laterally rather than upwards, the retention period of the vapor was longest at the lower levels in the soil. The concentration of the vapors diminishes with the lateral distance from the injection point, being low at 18 inches. This diminishing is definitely greater laterally than it is downward. The distribution of the vapor at the surface is not of consequence laterally for more than 6 inches.

2. *Soil of median moisture.* Chloropicrin vapor movement through soil of a moisture content of 20 to 25 per cent is shown in figure 5. It is seen that movement is more rapid than in dry soil and the distribution of the vapors is more uniform. Surface distribution is definitely improved. The retention time is diminished by approximately one-third. Lateral dispersion was found to be reduced since in no instance were the vapors detected at any lateral point 18 inches from the axis of injection. The difference in the dispersion picture in this case as contrasted with dry soil can probably be attributed to alterations in soil texture. In a colloidal type of soil as was used, changes in physical structure occur with increased moisture. The particles agglomerate, opening gross interspaces between the soil particles for the vapors to pass through instead of the very small spaces present when the soil exists as a dust.

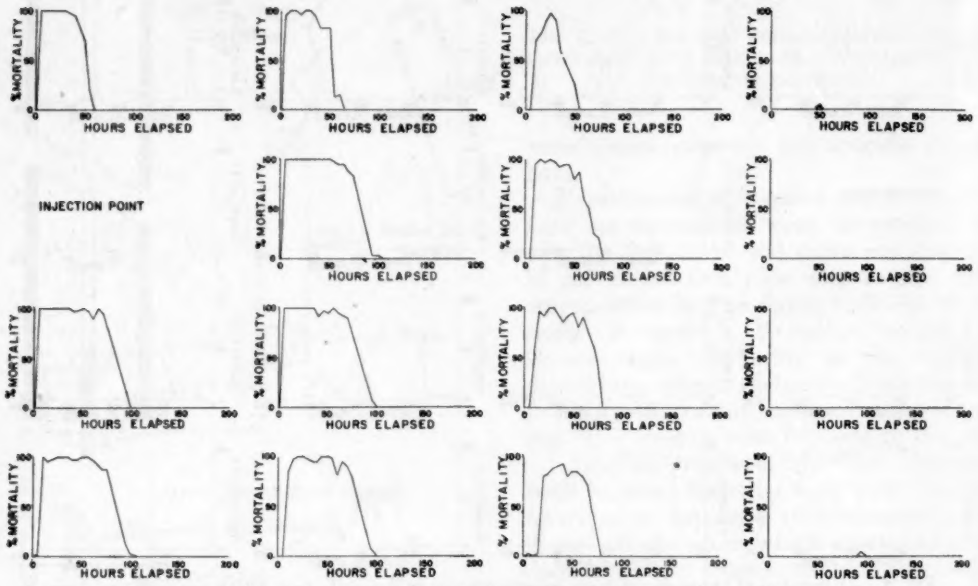


FIG. 5.—Dispersion of chloropicrin from the injection point in soil of median moisture content, circa 20–25 per cent moisture, expressed in terms of percentage mortality of the rice weevil.

3. *Wet soil.* When the soil moisture was adjusted to a level approximately that of its water holding capacity, the dispersal of chloropicrin as shown in figure 6 became considerably altered, with the evi-

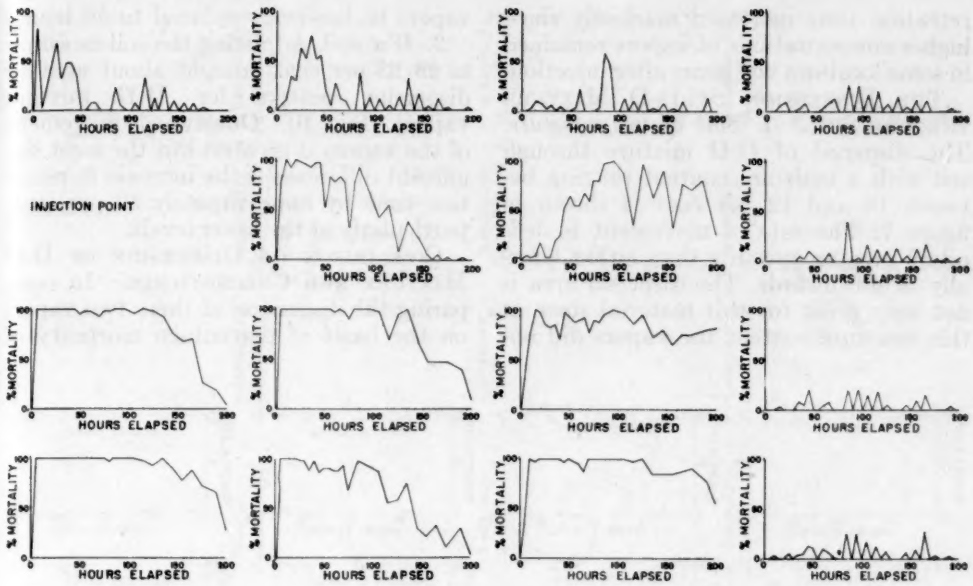


FIG. 6.—Dispersion of chloropicrin from the injection point in wet soil, circa 35 per cent moisture, expressed in terms of percentage mortality of the rice weevil.

dence indicating a downward movement of the vapors. In this instance the readings near the surface are shown though some doubt may be cast on their reliability. The success of the method depends on a close union between the soil and the sampling pipes which was difficult to maintain under higher moisture since even slight drying at the surface would cause the soil to crack away from the pipes. Lateral dispersal was about equal to that found in median moisture content soil but

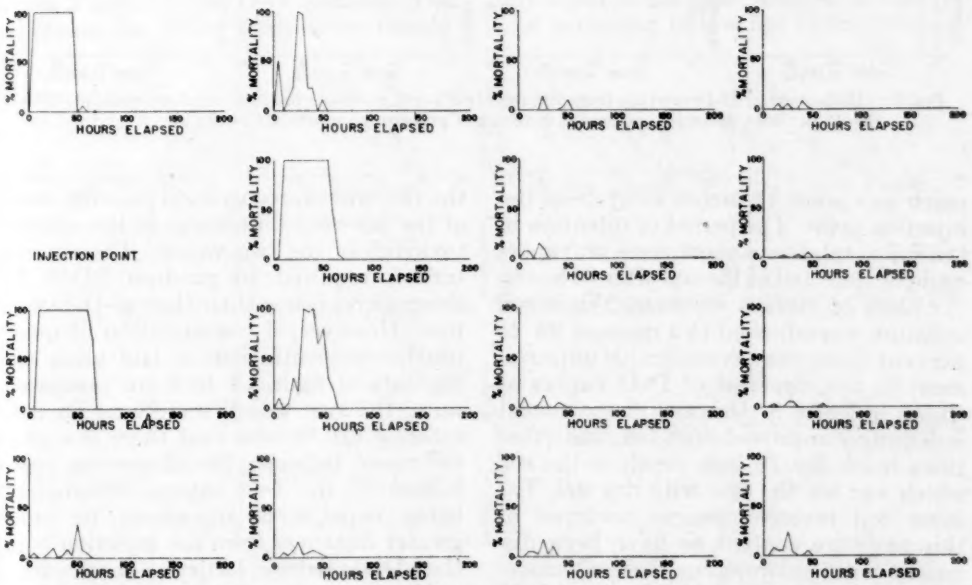


FIG. 7.—Dispersion of D-D mixture from the injection point in dry soil, circa 10–12 per cent moisture, expressed in terms of percentage mortality of the rice weevil.

retention time increased markedly since higher concentrations of vapors remained in some locations 200 hours after injection.

THE DISPERSION OF D-D MIXTURE THROUGH SOIL.—1. *Soil of low moisture.* The dispersal of D-D mixture through soil with a moisture content ranging between 10 and 12 per cent is shown in figure 7. The rate of movement is definitely greater upwards than either laterally or downwards. The dispersal area is not very great for this material since at this moisture content the vapors did not reach any point 12 inches away from the injection point. The period of retention in the soil is relatively short since no vapors could be detected in the soil after 65 hours.

2. *Soil of median moisture.* When soil moisture was adjusted to a range of 23–25 per cent there was a considerable improvement in the dispersal of D-D vapors as shown in figure 8. Downward movement is definitely improved since tangible quantities reach the 18 inch depth in the soil which was not the case with dry soil. The same soil texture changes occurred at this moisture content as have been discussed with chloropicrin. Lateral movement of vapors from the injection at 12 inches is seen. The retention time of the vapors is, however, reduced to 50 hours.

3. *Wet soil.* Adjusting the soil moisture to 28–33 per cent brought about another dispersion pattern for D-D mixture vapors (Fig. 9). Downward movement of the vapors is greatest but the most significant difference is the increase in retention time by approximately 50 per cent, particularly at the lower levels.

COMPARISON OF DISPERSION OF D-D MIXTURE AND CHLOROPICRIN.—In comparing the dispersion of these two vapors on the basis of percentage mortality of the rice weevil, recognition must be made of the inherent differences in the relative toxicities of the two vapors. The concentration required to produce LD50 for chloropicrin is less than that of D-D mixture. However, if consideration of quantitative concentrations is laid aside and the data of figures 4 to 9 are compared, using the rice weevil merely as an indicator, it can be seen that there is a great difference between the dispersion capabilities of the two vapors, chloropicrin being capable of dispersion to much greater distances from the injection point than D-D mixture. In dry soil both vapors tend to move upwards in the soil while in wet soil the reverse seems to be true.

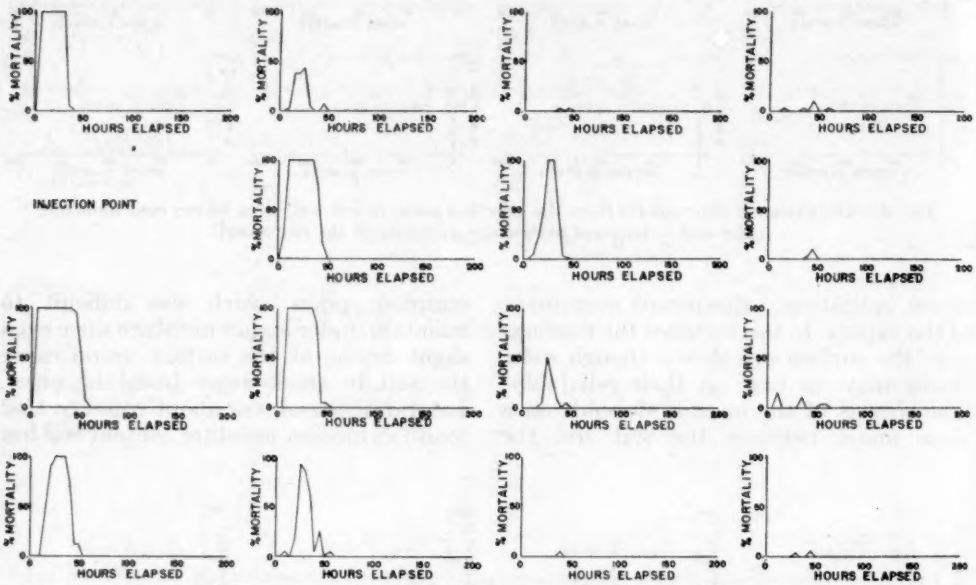


FIG. 8.—Dispersion of D-D mixture from the injection point in soil of median moisture content, circa 23–25 per cent moisture, expressed in terms of percentage mortality of the rice weevil.

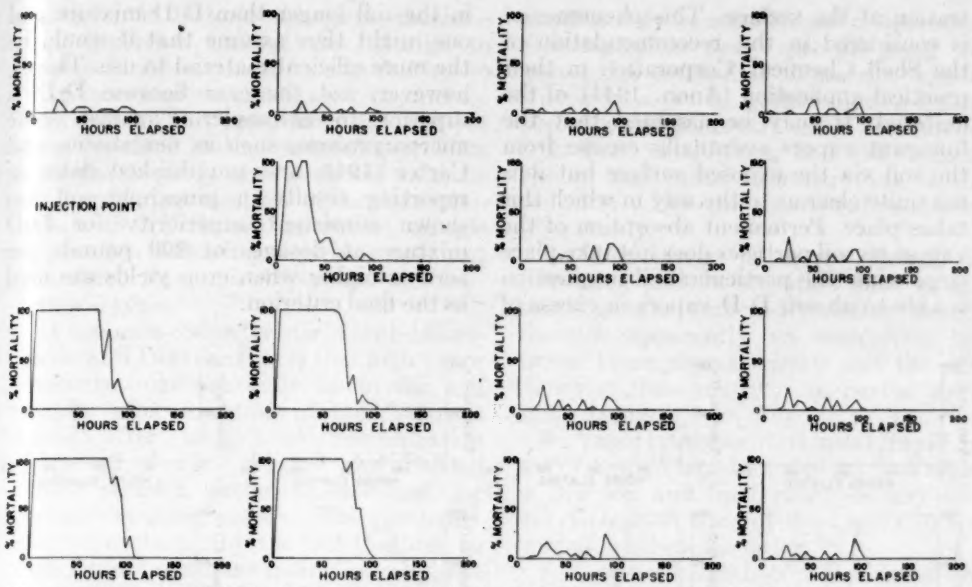


FIG. 9.—Dispersion of D-D mixture from the injection point in wet soil, circa 28–33 per cent moisture, expressed in terms of percentage mortality of the rice weevil.

Retention time for both vapors is reduced at median moistures and very greatly extended in very wet soil.

INFLUENCE OF DEPTH OF FUMIGATION.—A comparison of depth of injection on dispersion of chloropicrin and D-D mixture may be obtained by considering figures 4 and 10 for chloropicrin and figures 7 and 11 for D-D mixture. The conditions for these trials were closely parallel with the exception that the depth of injection was 12 inches for the respective materials as shown in figures 10 and 11. The most striking effect of increased depth of injection is the increased retention time for the vapors. With D-D mixture it is evident that the soil surface is not as effectively treated when the fumigant is put at too great a depth and there is an indication of lowered vapor concen-

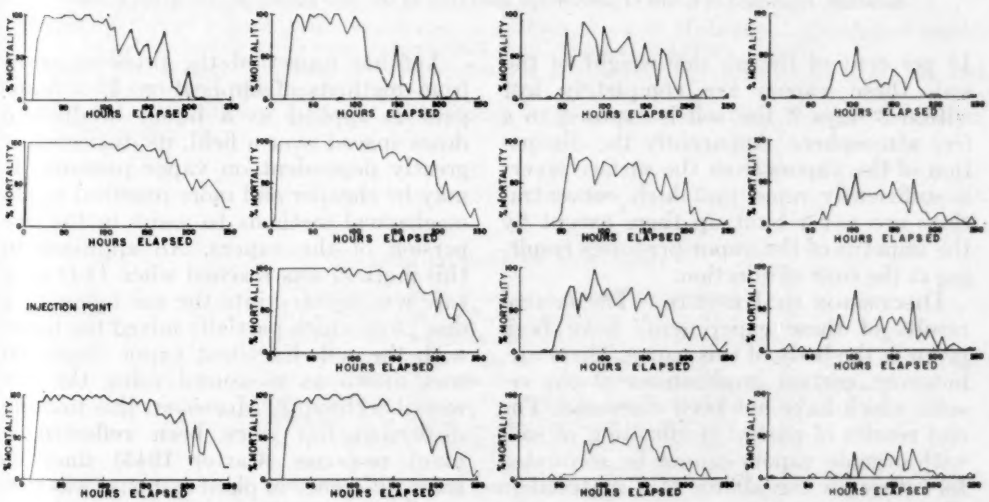


FIG. 10.—Dispersion of chloropicrin from the injection point, 12 inches deep, in soil of less than 10 per cent moisture, expressed in terms of percentage mortality of the rice weevil. Mulch paper cover.

tration at the surface. This phenomenon is considered in the recommendation of the Shell Chemical Corporation in their practical application (Anon. 1944) of the material. It may be assumed that the fumigant vapors eventually escape from the soil via the exposed surface but it is not quite clear as to the way in which this takes place. Permanent absorption of the vapors on soil particles does not take place since while the particular soil in question is able to absorb D-D vapors in excess of 15 per cent of the air dry weight of the soil, these vapors are completely lost within 3 days if the soil is exposed to a free atmosphere. Apparently the dissipation of the vapors from the surface layers is sufficiently rapid that high concentrations are never built up there except by the impetus of the vapor pressures resulting at the time of injection.

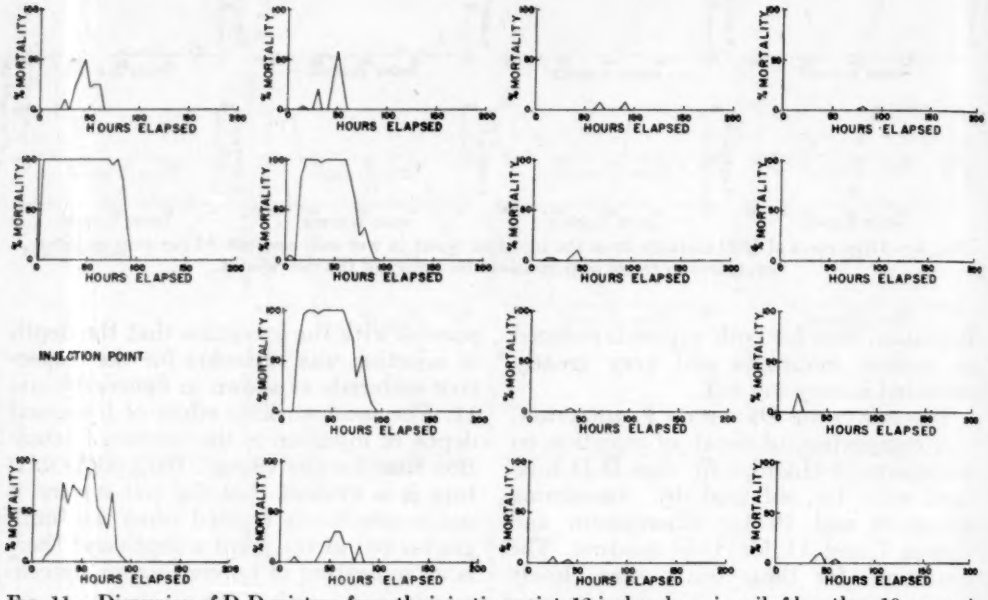


FIG. 11.—Dispersion of D-D mixture from the injection point, 12 inches deep, in soil of less than 10 per cent moisture, expressed in terms of percentage mortality of the rice weevil. Mulch paper cover.

DISCUSSION OF RESULTS.—The factual results of these experiments have been given in the body of this paper. There are, however, certain implications of the results which have not been discussed. The end results of partial sterilization of soils with organic vapors cannot be accounted for either on the ability of a material to disperse or remain in a soil mass. Actually chloropicrin disperses better and remains in the soil longer than D-D mixture and one might thus assume that it would be the more efficient material to use. This is, however, not the case because D-D is superior to chloropicrin against some microorganisms, such as nematodes, and Carter (1945, and unpublished data) in reporting results in pineapple soil has shown consistent superiority for D-D mixture at dosages of 200 pounds per acre or higher when crop yields are used as the final criterion.

Another aspect of the problem arises from methods of application. If a fumigant is applied as a liquid in discrete doses spaced over a field, its dispersion is greatly dependent on vapor pressure. It may be cheaper and more practical to use mechanical methods to assist in the dispersion of the vapors. An approach to this method was reached when D-D mixture was injected into the soil following a disc plow which partially mixed the liquid with the soil. Excellent vapor dispersion was shown as measured using the rice weevil technique. Moreover, this uniform dispersion has since been reflected in plant response (Carter 1945) since no great difference in plant response was seen whether the dosage was 200 pounds per acre or 750 pounds per acre, suggesting

that even at the lower dosage the mechanical dispersion enabled the material to approach its maximum potentialities so that increased dosage ceased to operate as a factor. This experiment has not yet been repeated and constitutes a problem for separate study since adequate methods for mechanical mixture of fumigant liquids with soil do not now exist. Simple application following a plow would not guarantee thorough dispersion with certain soil types.

A common characteristic of both chloropicrin and D-D mixture is that high vapor concentrations are built up in the soil rapidly after injection of the fumigant liquid after which the concentration drops off slowly. Higgins and Pollard (1937) noted a similar phenomenon for carbon bisulfide vapors. This probably may be explained by the fact that due to high vapor pressures existing initially, the vapors are absorbed quickly by the soil and are then released at a slower rate by virtue of the necessity of the vapors to escape through the soil interstices.

SUMMARY.—1. The movement of chloropicrin and D-D mixture was measured continuously by means of a semi-quantitative biological assay method using the percentage mortality of the rice weevil, *Sitophilus oryza* L., as the criterion for the presence and concentration of the vapors.

2. Both chloropicrin and D-D vapors rise to high initial concentrations in the soil after which the concentration diminishes slowly.

3. Chloropicrin is more efficient in dispersion and its retention time in the soil is greater than D-D mixture though there is apparently no correlation between these characteristics and the efficiency of these materials as partial sterilizing agents.

4. Vapor movement is most rapid in soil of median moisture content, less rapid in dry soil and least rapid in very wet soil. Retention time of the vapors in the soil follows the same order.

5. Increased depth of injection of the fumigant liquids extends the retention time of the vapors but apparently reduces the efficiency of the vapors near the soil surface, particularly in the case of D-D mixture.—3-11-44.

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## ENTOMOLOGISTS IN THE ARMY

"The list of new permanent career officers selected for the Army and Air Force announced October 10, 1947 included four entomologists. These officers and their present assignments are: Captain Walter J. LaCasse, 207th Malaria Survey Detachment, Okayama, Japan; Captain Davidson B. Lieux, Station Hospital, Fort Knox, Kentucky; Lieutenant Herbert C. Barnett, Medical Field Service School, Brooke Army Medical Center, Fort Sam Houston, Texas, and Lieutenant Joseph W. Jones, Jr., at present unassigned."

# Host Plants of the Cabbage Seedpod Weevil

CHARLES F. DOUCETTE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Three types of feeding occur in the life cycle of the cabbage seedpod weevil, *Ceutorhynchus assimilis* (Payk.). There are two periods of adult feeding. In the summer months the newly emerged weevils feed rather voraciously and then seek hibernation quarters. The limited observations on the host plants involved in this prehibernation feeding period indicate that almost any thick green part of the common *Brassica* and *Raphanus* plants is acceptable. Whether other plants are acceptable has not been determined. Stems, the larger veins on leaves, and particularly pods that are not quite mature are the feeding places of the emerging weevils. At the time of emergence blossoms or buds of these crucifers are rather scarce, but weevils may be found on those available, particularly on the buds. In cabbage-seed fields that are nearly ready for cutting these weevils have been observed on the terminal pods, the last to mature. At times 15 to 20 weevils have been noted on one pod. Seeds are frequently punctured in this type of feeding, but as only the last few ripening pods are involved the proportion of damaged seeds seldom is large.

The second period of feeding takes place in the spring, when the adults emerge from hibernation quarters about the time the earlier crucifiers start to bloom. It appears that the weevils then feed almost entirely on the buds and flowers of *Brassica* and *Raphanus*, although adults have been observed on flowers of other crucifers. Occasionally the weevils bore into the buds. The weevils are frequently found deep in the throats of the flowers. While at times this may be for shelter, their activities indicate a search for nectar. The weevils pay no attention to the anthers, nor have they been observed eating pollen; yet, through their movements, they probably serve as pollinators.

Some accounts of the habits of this weevil have indicated that females deposit eggs in the ovules of the plant before the petals fall. Exact observation of the weevil activity within a flower has been extremely difficult. However, the adults have been watched many times for evidence of their feeding on the ovules, and nothing of this nature has been observed. Observations on oviposition indicate that pods are not selected until some time after petal-fall, and in extensive examinations of young pods no eggs have been found within pods less than 2 mm. in diameter. The female makes a hole in the pod wall with its beak and then turns around to place an egg inside the pod. The feeding puctures in the buds and the egg punctures in the pods are the only post-hibernation injuries observed in green tissue.

The third type of feeding is that done by the larva. This feeding is the principal cause of economic damage. The primary food of the larva is the developing seed, and there is some feeding on the tissues between the seeds as the larva moves from one seed to another within a pod. Larval attack has been found only in plants of the genera *Brassica* and *Raphanus*, although pods of other crucifers have been examined for larval injury.

The genus *Raphanus* has two species—*R. sativus*, which includes the garden radishes and wild forms, and *R. raphanistrum*, a wild plant called wild radish or jointed charlock. Both species are attacked by larvae of *Ceutorhynchus assimilis*. Since the seeds are large, larvae frequently complete their development within single seeds, but occasionally will feed on two or, less frequently, three within a pod. In 17 pod samples of *R. sativus* the mean number of seeds damaged by a larva was 1.93, minimum 1 and maximum 4. The mean for 6 pod samples of *R. raphanistrum* was 1.17 seeds, minimum 1 and maximum 3.

The genus *Brassica* includes a number of important food plants, as well as several wild forms. Cabbage, cauliflower, collard, kale, brussels sprouts, broccoli, and kohlrabi are all forms of *B. oleracea*. Rutabaga, turnip, rape, and Chinese cabbage are other species of *Brassica*. There are also several species in the mus-

[1] In cooperation with the Washington Agricultural Experiment Station; the Washington State Department of Agriculture; the County of Skagit, State of Washington; the Northwest Agricultural Laboratory, Mt. Vernon, Washington; and the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

tard group—*B. hirta* (*alba*) (white mustard), *B. nigra* (black mustard), and *B. juncea* (Indian mustard)—which are grown for use as condiments or as a source of oil. Several horticultural types of mustard are grown for use as greens. Most of these are horticultural varieties of *B. juncea*. Two species, *B. campestris* (wild turnip) and *B. kaber* (charlock), grow wild in the Pacific Northwest.

Cabbage-seed production has been seriously affected by the cabbage seedpod weevil in the Pacific Northwest. An opportunity to consider the relative susceptibility of several varieties of cabbage was afforded in an experiment set up by Glenn Pound for virus studies at the Northwest Agricultural Laboratory Mount Vernon, Washington, in 1945. Fourteen varieties of cabbage were planted in a randomized block pattern with three replications. Uniform pod samples were collected from each plot and examined to determine the extent of infestation. The number of larvae attacking the pods in each sample was used as an index of the intensity of infestation. The total numbers of larvae infesting these varieties of cabbage were as follows:

| | |
|---|---|
| Penn State Ballhead | 189 |
| Resistant Detroit | 204 |
| Glory of Enkhuizen | 212 |
| Marion Market | 216 |
| Ferry's Round Dutch | 241 |
| Bugner | 243 |
| Globe | 246 |
| Charleston Wakefield | 261 |
| Jersey Queen | 263 |
| Stein's Flat Dutch | 286 |
| All Head Select | 302 |
| Succession | 316 |
| Ferry's Hollander | 322 |
| Wisconsin Ballhead | 391 |

Difference required for significance at 5 per cent level—55.
Differences required for significance at 1 per cent level—74.

It is evident that there is considerable difference in the susceptibility of the varieties to attack by the cabbage seedpod weevil.

Studies were made at the Sumner, Washington, laboratory of the Bureau of Entomology and Plant Quarantine, to determine preferences of the weevils for various cultivated and wild forms of *Brassica* and *Raphanus*. This involved three types of planting—namely, young plants set in the fall, seed planted in place in the fall, and seed planted in place in the spring. Randomized-block arrangements were used, with four replications in 1944–45, and five replications in 1945–46. When mature, pod samples were collected and examined to determine the extent of larval attack. The total numbers of larvae attacking 100 pods of each host in 1945 were as follows:

| | |
|---|---|
| *Brassica hirta* (*alba*) | 0 |
| *B. nigra* | 7 |
| Radish, Early Scarlet Turnip (spring-planted) | 85 |
| Radish, Chinese Rose (fall-planted) | 103 |
| *B. juncea* | 115 |
| Mustard, Southern Giant Curled | 120 |
| Kale, Green Scotch Curled | 154 |
| Cabbage, Penn State Ballhead | 160 |
| Kohlrabi | 167 |
| Turnip, Purple Top White Globe | 174 |
| Brussels sprouts | 179 |
| Rutabaga | 181 |
| *B. campestris* | 186 |
| Cabbage, Copenhagen Market | 191 |
| Broccoli, Green Sprouting | 201 |
| Rape, Dwarf Essex | 225 |
| Turnip, Shogoin | 237 |
| Chinese cabbage (fall-planted) | 270 |
| Chinese cabbage (spring-planted) | 289 |

Since there were several missing plots including one in each of the three hosts having the highest infestations, the data of this series were not subjected to statistical analysis.

An amplified series covering more species was started in the summer of 1945. Pod samples from these plots were collected in the summer of 1946 and examined for larval attack. The numbers of larvae infesting 100 pods of each host were as follows:

| | |
|---|---|
| *Brassica hirta* (*alba*) | 0 |
| *B. nigra* | 1 |
| *B. kaber* (*arvensis*) | 10 |
| Radish (fall-planted) | 74 |
| Radish (spring-planted) | 79 |
| Turnip, Purple Top White Globe | 89 |
| *B. juncea* | 93 |
| Rutabaga | 98 |
| *B. campestris* (fall-planted) | 98 |
| *B. campestris* (spring-planted) | 110 |
| Kale, Dwarf Siberian | 113 |
| Chinese cabbage (fall-planted) | 126 |
| Kale, Green Scotch Curled | 139 |
| Mustard, Tendergreen | 142 |
| Turnip, Shogoin (fall-planted) | 146 |
| Kohlrabi | 147 |
| Rape, Dwarf Essex | 147 |
| Cabbage, Penn State Ballhead | 151 |
| Brussels sprouts | 162 |
| Cabbage, Stein's Flat Dutch | 177 |
| Cabbage, Golden Acre | 182 |
| Chinese cabbage (spring-planted) | 184 |
| Turnip, Shogoin (spring-planted) | 234 |

Difference required for significance at 5 per cent level—25.
Difference required for significance at 1 per cent level—32.

It is evident that there are distinct differences in the susceptibility of the species and varieties of host plants to weevil at-

tack. *Brassica hirta* appears to be immune. The few indications of possible larval presence in pods of *B. nigra* are questionable. Several samples of pods from wild *B. nigra* plants were collected in southern Oregon, and all were found to be free of infestation. *Brassica kaber* was attacked only to a very limited extent. *Brassica juncea* and *B. campestris* were attacked moderately. Because *B. campestris* is widespread in the Pacific States, this plant is probably the most important single host involved in natural spread of the weevil throughout the Pacific Slope and in the maintenance of populations in areas where there is no commercial production of susceptible seed crops.

While larval populations in radish were not very high, this plant is subject to sufficient injury to cause concern. Larvae in radish pods are apparently beyond reach of ovipositing parasites, and little mortality results from parasitism. Hence larval survival is higher than in *Brassica* pods. Wild radish is an important factor in weevil spread and in population maintenance in areas where it is abundant.

The other plants tested were garden types of several species of *Brassica*. While there was considerable variation in preference, the infestation in all was high. Chinese cabbage and Shogoin turnip were distinctly preferred above the others. However, fall-planted lots of both came into bloom so early that by the time the weevils were ready to deposit their eggs many of the pods were no longer suitable. Hence the infestation was considerably less in the fall-planted lots.

An unusual condition has been observed in kohlrabi pods in western Washington. While larval attack has been high, almost all the larvae have succumbed before becoming half-grown. This mortality appears to have been caused by proliferating tissue between the seeds in the pods.

Numerous samples of infested material have been collected in commercial seed plantings and from wild hosts in areas of general infestation. The trends of infestation have been comparable with those shown in the Sumner studies. Chinese cabbage has consistently been the most severely damaged. Differences in infestation in cabbage were due largely to the varietal factor, but cabbage has generally been more heavily infested than rutabaga or turnip in the same area. Infestation in kale has been lower than in rutabaga and turnip. Larval attack on radish seed crops has been somewhat less severe than on the commercial *Brassica*. *Brassica kaber* samples have been collected in a number of localities, some close to commercial seed plantings and some mixed with other crucifers. Many of them have been free from larval attack, and others have been attacked only lightly. Infestation in wild *B. campestris* has corresponded in a general way to that in cabbage. Infestation in wild radish has corresponded closely to that in commercial radish crops.

SUMMARY.—Three types of feeding occur in the life cycle of the cabbage seedpod weevil, *Ceutorhynchus assimilis* (Payk.). Before hibernation adults feed on thick green parts of *Brassica* or *Raphanus* plants. Some seed damage results from the feeding of these adults on immature pods. After hibernation the adults feed primarily on nectar, largely in flowers of *Brassica* and *Raphanus*, but also in those of other crucifers. They also bore into unopened buds, and the female weevils make holes in the pod walls preceding oviposition. The third type of feeding is that of the larvae, which feed on the seeds developing within the pods.

In studies made in western Washington and Oregon larval attack has been found only in plants of *Brassica* and *Raphanus*. *Brassica hirta* (*alba*) (white mustard) and *B. nigra* (black mustard) are apparently immune, and *B. kaber* (charlock) is subject to only very limited attack. Larval populations in radish pods are not so great as in *Brassica*, but cause considerable damage to seed. *Brassica juncea* (Indian mustard) and *B. campestris* (wild turnip) are both attacked moderately. The widespread occurrence of the latter and the somewhat localized occurrence of wild radishes are important factors in the spread of the weevil and in the maintenance of populations in areas where there is no commercial seed production of susceptible host plants.

There is considerable variation in the susceptibility of the several garden types of *Brassica* to weevil attack, but all appear to be subject to serious damage. Varieties of cabbage differ in susceptibility. Kohlrabi also is attacked, but larvae appear unable to complete their development in pods of this plant.—8-8-47.

# Oviposition and Longevity of Chinch Bugs on Seedlings Growing in Nutrient Solutions

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During the course of experimental work on the resistance of sorghum varieties to the chinch bug, *Blissus leucopterus* (Say), efforts have been made to explain differences in resistance among the varieties. Dahms *et al.* (1936) found in laboratory tests that chinch bugs laid more eggs, lived longer, developed faster, and grew larger on varieties of sorghum that are susceptible to the bugs in the field than on varieties that are resistant. Webster & Mitchell (1940) made nitrogen-fraction determinations on some sorghums and found that susceptible field-grown Dwarf Yellow milo plants were higher in nitrogen content than resistant Atlas sorgo. The greatest varietal difference was in the percentage of amino nitrogen. They concluded that it was this fraction, together with the basic fraction (largely diamino acids), that accounted for the higher percentages of soluble nitrogen found in the Dwarf Yellow milo plants. Dahms & Fenton (1940) showed that resistance of both Atlas sorgo and Finney milo to the chinch bug was consistently decreased by the addition of sodium nitrate to the soil and, in the majority of cases, increased by the addition of superphosphate as a fertilizer.

With these results as a basis, a study was initiated at Lawton, Oklahoma, in 1939 to investigate the effect of phosphorus, nitrogen, and other plant nutrients on the oviposition and longevity of chinch bugs. The results of this study obtained in 1940 and 1941 in Oklahoma are presented.

Experimental Procedure.—The container used for growing the plants consisted of a strip of metal 2 inches wide soldered around the outside of the upper part of the threaded collar of a two-piece mason jar lid. The hole in the top of the collar was covered with a piece of half-inch-mesh wire screen, soldered in place. This cuplike device could be screwed onto a fruit jar with the screen just above the top of the jar. A layer of excelsior was stuffed into the cup against the screen bottom until it was about half full. A piece of wet tissue paper was then placed over the excelsior, the seeds were spaced as desired on the paper, another piece of wet tissue paper was placed over the seeds, and then another layer of excelsior to fill the cup. All the excelsior was then moistened and the attachment supported in a pan of tap water so that the bottom of the excelsior was in contact with the water. When the roots extended about an inch below the screen, the apparatus was screwed onto a quart jar of the gravel culture.

Muscatine gravel, the granules of which were an eighth to a quarter inch in diameter, was used for the cultures. This was a Mississippi River gravel from which all but about 5 per cent of calcium carbonate had been leached.

The jars were filled to within 1 inch of the top with gravel, and the nutrient solutions added until the jars were full. Under ordinary conditions the solutions were changed every 4 to 6 days. After the plants had grown in the jars for about 8 days in 1940, and about 12 days in 1941, they were transferred to individual chinch bug oviposition cages.

A cage consisted of a transparent celluloid tube about 70 mm. long and 25 mm. in diameter and contained one plant. One end of the tube was covered with muslin, and the other end closed with the larger end of a tight-fitting split rubber stopper. A plant was taken from the nutrient solution and placed between the halves of the stopper with the leaves inside the tube and the roots extending below the stopper. The roots and the smaller end of the stopper were then inserted into a shell vial that was almost full of the same nutrient solution as that from which the plants were taken. Three pairs of chinch bugs were placed in each cage, and generally 10 cages were used for each variety of sorghum and in each solution. Egg counts were made every 48 hours, at which time fresh sorghum plants were put into each cage.

The stock solutions used in making up nutrient solutions were 0.5-molar concentrations of magnesium sulfate, calcium nitrate, potassium dihydrogen orthophos-

phate, potassium nitrate, potassium sulfate, ammonium nitrate, and calcium chloride; 0.05-molar concentration of calcium hydrogen orthophosphate; 0.01-molar concentration of calcium sulfate; 2-per cent concentration of ferric citrate; and a supplementary solution. The supplementary stock solution was one suggested by Hoagland & Arnon (1938) and consisted of the indicated amounts of the following compounds per liter of water: boric acid 2.86 grams; manganese chloride 1.81 grams; zinc sulfate 0.22 gram; copper sulfate 0.08 gram and molybdic acid (assaying 85 per cent $MoO_3$) 0.09 gram. Distilled water was also used for comparison.

solution the amount of calcium nitrate and potassium nitrate was reduced and potassium sulfate and calcium sulfate increased; therefore the sulfate concentration was comparatively high in this solution.

The plants were grown in a cloth-covered outdoor insectary, which kept out the direct rays of the sun but allowed sufficient light for good plant growth. The average temperature in the insectary during the 1940 experiments was 78° F.

For the first-generation bugs and 71° for those of the second generation. In 1941 the average temperatures were 72° and 67° for the first and second generations, respectively.

**Table 1.—Parts per million of different elements or radicals used in each nutrient solution.[1]**

| Nutrient Solution | Magnesium | Calcium | Potassium | Ammonium | Nitrate | Phosphate | Sulfate |
|---|---|---|---|---|---|---|---|
| Complete solution | 60 | 200 | 214 | 0 | 868 | 142 | 240 |
| High phosphorus | 60 | 260 | 214 | 0 | 806 | 522 | 240 |
| Low phosphorus | 60 | 180 | 214 | 0 | 868 | 47 | 240 |
| High nitrogen | 60 | 200 | 253 | 108 | 1302 | 142 | 240 |
| Low nitrogen | 60 | 126 | 214 | 0 | 134 | 142 | 590 |
| High chlorine[2] | 60 | 300 | 224 | 0 | 806 | 142 | 240 |

[1] All solutions also contained the following elements: Boron 0.5 p.p.m., manganese 0.5 p.p.m., zinc 0.05 p.p.m., copper 0.02 p.p.m. and molybdenum 0.01 p.p.m.
[2] This solution contained in addition 274 p.p.m. of chlorine and 84 p.p.m. of sodium.

The nutrient solution jars were painted on the outside with black asphalt paint to prevent algae from growing in the solutions. All solutions except distilled water received the same quantity of ferric citrate and supplementary solution at the beginning. Table 1 shows the solutions used and the concentration of each element or radical. The so-called complete solution signifies one which contained all essential elements in sufficient quantity for normal plant growth. All the solutions except distilled water were kept at about *p*H 6 by adding dilute hydrochloric acid or sodium hydroxide. It was, of course, impossible to vary one element without varying another, but in all cases the variations of potassium, phosphate, and nitrate were kept at a minimum, except where the last two mentioned were deliberately made high or low. Since previous field and laboratory results indicated that the amount of potassium in the soil did not influence resistance of sorghums to the chinch bug, this element was not varied materially in these solutions. To make the low-nitrogen

After the plants had been growing in the solutions for approximately 10 days, samples of plants from cages containing each solution were analyzed for total nitrogen, phosphorus, and chlorine.[1]

The bugs were collected in the field when they were in the fifth instar and caged on the variety of sorghum growing in the solution on which they were to be tested. When the bugs became adult, three pairs were placed in each cage. The fifth-instar bugs for studying the first generation were collected from barley, and those for studying the second generation were from the same variety of sorghum on which the bugs were to be colonized.

Experimental Results and Discussion.—The data obtained from Finney milo are shown in table 2, together with the percentages of nitrogen, phosphorus, and chlorine in the plants. The percentage of nitrogen was approximately the same

[1] These analyses were made by James E. Webster, of the Agricultural Chemistry Research Department, Oklahoma Agricultural Experiment Station.

for plants growing in all solutions, except the low nitrogen and distilled water. The percentage of nitrogen in plants growing in a high-nitrogen solution was not so high as that in plants growing in the complete solution, even though the nitrate content was 1302 p.p.m. for the former as compared with 868 p.p.m. for the latter. Plants growing in the high-phosphorus solution contained much more phosphorus than those growing in any of the other solutions.

The difference in oviposition on the plants growing in the various solutions was not nearly so great in 1940 as in 1941. However, in both years and for both generations more eggs were laid on plants growing in high-nitrogen than in low-nitrogen solution, and in low-phosphorus than in the high-phosphorus solution. First-generation female bugs lived longer on plants growing in distilled water alone than on those growing in most of the other solutions, and also laid a surprisingly large number of eggs. This seems to indicate that the endosperm of the Finney milo seed contained enough suitable nutrients so that the seedling plants were favorable for chinch bug development. In most cases, especially for first-generation bugs, those that laid a large number of eggs lived a shorter time than those that laid fewer eggs. The daily average number of eggs per female was considerably lower when the bugs fed on plants growing in distilled water or in solutions that were low in nitrogen, high in phosphorus, or high in chlorine, than when they were fed on plants growing in high-nitrogen or low-phosphorus solutions. It may be noted that the nitrogen-phosphorus ratio was much lower for the plants growing in high-phosphorus and low-nitrogen solutions, on which oviposition was low, than for the other solutions. It cannot be concluded, however, that a low nitrogen-phosphorus ratio in the plant is always associated with low oviposition, since plants growing in the high-chlorine solution had the highest nitrogen-phosphorus ratio and still bugs feeding on these plants laid relatively few eggs.

The results obtained with Atlas sorgo growing in the various solutions are presented in table 2. The chemical analysis of the Atlas plants used in these tests indicated that the amount of nitrogen was approximately the same as that found in the Finney milo plants grown in similar solutions. In most cases the phosphorus content of the Atlas sorgo plants was considerably higher than that found in the Finney milo plants, though apparently not enough so to be responsible for the much lower oviposition and shorter life of the bugs caged on Atlas sorgo. In general, the results indicate that the much lower oviposition and shorter life of females on

**Table 2.—Average oviposition and longevity of chinch bug females feeding on sorghum seedlings growing in different culture media, Lawton, Oklahoma, 1940 and 1941.**

| Culture Medium | Elements in Plants | | | Nitrogen Phosphorus Ratio | Eggs per Female | | | Longevity of Females | | | Eggs Per Day |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nitrogen | Phosphorus | Chlorine | | First Generation | Second Generation | Total Compared With Check[1] | First Generation | Second Generation | Average Compared With Check[1] | |
| | *Per Cent* | | | | *Number* | | *Per Cent* | *Days* | *Days* | *Per Cent* | *Number* |
| *Feeding on Finney Milo* | | | | | | | | | | | |
| Distilled water | 2.13 | 0.352 | 1.012 | 6.05 | 147.1 | 21.5 | 74.7 | 61.4 | 35.5 | 116.9 | 1.74 |
| Complete solution | 4.12 | .529 | 1.223 | 7.79 | 189.0 | 36.7 | 100.0 | 45.9 | 37.0 | 100.0 | 2.72 |
| High phosphorus | 4.02 | .831 | 1.066 | 4.84 | 166.4 | 30.3 | 87.2 | 48.6 | 29.0 | 93.6 | 2.53 |
| Low phosphorus | 4.03 | .464 | 1.063 | 8.69 | 205.5 | 43.0 | 110.1 | 46.2 | 35.4 | 98.4 | 3.04 |
| High nitrogen | 4.06 | .444 | .844 | 9.14 | 238.2 | 50.7 | 128.0 | 48.8 | 38.1 | 104.8 | 3.33 |
| Low nitrogen | 2.35 | .513 | 1.137 | 4.58 | 170.6 | 27.8 | 87.9 | 55.5 | 36.6 | 111.1 | 2.15 |
| High chlorine | 3.97 | .413 | 2.169 | 9.61 | 147.0 | 33.6 | 80.0 | 46.1 | 28.3 | 89.7 | 2.43 |
| *Feeding on Atlas sorgo* | | | | | | | | | | | |
| Distilled water | 1.83 | .304 | 1.089 | 6.02 | 2.8 | 0.5 | 14.5 | 18.3 | 14.5 | 62.5 | 0.10 |
| Complete solution | 4.19 | .722 | .766 | 5.80 | 20.2 | 2.5 | 100.0 | 33.7 | 18.8 | 100.0 | .43 |
| High phosphorus | 4.08 | .767 | 1.320 | 5.32 | 9.8 | 4.5 | 63.0 | 26.4 | 17.3 | 83.2 | .32 |
| Low phosphorus | 4.02 | .542 | .801 | 7.42 | 22.2 | 7.6 | 131.3 | 35.7 | 20.0 | 104.0 | .54 |
| High nitrogen | 4.23 | .688 | .867 | 6.15 | 20.5 | 5.9 | 116.3 | 32.6 | 14.9 | 90.5 | .56 |
| Low nitrogen | 2.90 | .750 | 1.480 | 3.87 | 6.1 | 1.5 | 33.5 | 27.6 | 16.9 | 84.8 | .17 |
| High chlorine | 4.11 | .738 | 1.842 | 5.57 | 13.0 | 4.3 | 76.2 | 30.6 | 17.5 | 91.6 | .36 |

[1] Complete solution used as check.

Atlas sorgo than on Finney milo are apparently due more to inherent, though as yet unknown, difference between the two varieties than to differences in the reactions of these varieties to scarcity or abundance of nitrogen, phosphorus, or chlorine in the soil. On both varieties, however, the bugs feeding on plants growing in low-nitrogen or high-phosphorus solutions laid fewer eggs than bugs fed on plants growing in high-nitrogen or low-phosphorus solutions.

There were no material differences in the longevity of females feeding on Atlas sorgo plants growing in the different nutrient solutions, except that they survived a much shorter time on plants grown in distilled water than on those grown in solutions to which nutrients had been added. Atlas plants growing in distilled water proved to be a very poor food for chinch bugs, as none of the bugs feeding on Atlas sorgo lived nearly so long as those feeding on Finney milo.

During the initial 30 days first-generation bugs feeding on Finney milo laid many more eggs on the plants growing in low-phosphorus or high-nitrogen solutions than on plants growing in high-phosphorus or low-nitrogen solutions. Then there was, in most cases, a 10 to 15-day period during which they laid about equal numbers on the plants growing in all four solutions. Thereafter the bugs laid slightly more eggs on plants growing in high-phosphorus than in low-phosphorus solutions and more on plants in low-nitrogen than in high-nitrogen solutions. This was not true of Atlas sorgo, or of second-generation bugs on Finney milo, where less than 75 or 100 eggs were laid per female. These results indicate that a high rate of oviposition cannot be sustained over a long period even though the food is very favorable.

From the data obtained in these experiments, soils low in nitrogen and high in phosphorus or chlorine would be expected to be less favorable for chinch bug multiplication on Finney milo and Atlas sorgo than soils high in nitrogen or low in phosphorus. In the same manner the addition of nitrogen to soils deficient in this element apparently would be favorable to the chinch bug, whereas the addition of phosphorus to soils deficient in that element apparently would decrease chinch bug infestation.

SUMMARY.—A study was made to determine the effect of different plant nutrients on the resistance of sorghum plants to the chinch bug, *Blissus leucopterus* (Say). Finney milo and Atlas sorgo plants were grown for 8 or 12 days in different nutrient solutions and then transferred to cages, where chinch bugs were allowed to feed on them.

Under these conditions chinch bugs laid more eggs on plants growing in solutions high in nitrogen or low in phosphorus than on the same varieties growing in solutions that were low in nitrogen or high in phosphorus. The differences were not nearly so great, however, as those between the two varieties of plants growing in the same solutions.

The longevity of females feeding on Atlas sorgo plants did not appear to be affected by the nutrient solution, except that it was considerably lower on plants growing in distilled water. None of the bugs feeding on this variety lived so long as those feeding on Finney milo. First-generation females feeding on Finney milo growing in distilled water lived longer than those feeding on plants growing in any of the other solutions. As many eggs were laid by these bugs as were laid on plants growing in the high-chlorine solution, and almost as many as were laid on plants growing in high-phosphorus and low-nitrogen solutions. This indicated that Finney milo seed contained suitable nutrients, so that the seedlings were favorable for chinch bug development. In general, females lived longer on Finney milo plants growing in the solutions which caused a comparatively low rate of oviposition.

On plants growing in most solutions where the nitrogen-phosphorus ratio was low, the total and average daily egg deposition per female was also low, but when this ratio was high the chinch bugs did not always lay a large number of eggs.

During the first 30 days first-generation bugs feeding on Finney milo plants growin in low-phosphorus or high-nitrogen solutions usually laid many more eggs than on plants growing in high-phosphorus or low-nitrogen solutions. During the next 10 or 15 days about an equal number of eggs were laid on plants in all solutions, and thereafter the bugs often laid slightly more eggs on the high-phosphorus or low-nitrogen plants.—9-18-47.

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# Control of Vineyard Insects with DDT, with Special Reference to the Japanese Beetle and the Grape Berry Moth

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A preliminary test with DDT in a commercial vineyard near Holmdel, N. J., early in August 1943, indicated that DDT had promise for controlling the Japanese beetle, *Popillia japonica* Newm., provided it could be used in a program which would also give adequate control of the grape berry moth. *Polychrosis viteana* (Clem.), and black rot caused by *Guignardia bidwellii* (Ellis) Viala & Ravaz. This vineyard, of 70 acres, heavily infested with the grape berry moth, and generally infected with black rot, was also used in 1944, 1945, and 1946 for experiments on the control of these pests. There were no other commercial vineyards in the vicinity.

The grower undertook a program of sanitation in 1944 as an aid in controlling the grape berry moth and the diseases that are carried through the winter on or within old leaves, mummified fruit, and vines. The prunings from the vines were burned instead of being used between the rows as a means of reducing erosion. Weeds were practically eliminated from the trellis strips by burning, cutting, and cultivation. Early in the spring the ridged trellis strips were pulled out and turned over to bury the mummified fruit and old leaves; later the furrows were thrown back to restore the ridge in the trellis strips.

In this vineyard there appeared to be at least two broods of the grape berry moth. First-brood larvae appeared in June, during and after blossoming, and fed in the blossoms and in the newly formed berries. Second-brood larvae attacked the maturing fruit late in July and in August. In view of the difficulty of obtaining adequate coverage of the fruit with a spray in mid-summer, because of the protecting canopy of leaves and the hazard of building up an excessive residue on the fruit, it was hoped to obtain control of the grape berry moth by controlling the first brood.

MATERIALS AND PREPARATION OF SPRAYS.—*DDT.* During 1944 and 1945 technical DDT was used. It was conditioned by micronizing[2] with an equal weight of pyrophyllite. This conditioned DDT was prepared for spraying in the following manner: The 50-per cent DDT was placed in a pail and a solution of fish glue (1 lb. per gallon of water) was added as a wetting agent at the rate of 1 pint for each 2 pounds of solids. Water was added gradually with constant stirring until the mixture was worked into a stiff paste and then further diluted until a thin paste was obtained. This paste was poured into the tank through the screen when the tank was three-quarters full. In 1946 a commercial micronized material containing 50 per cent of technical DDT, pyrophyllite, and a little wetting agent was used. Although this material wetted readily, it was made into a thin paste before being added to the spray tank. In this report the DDT is referred to as pounds of actual DDT, not the 50-per cent material, per 100 gallons of spray.

*Fermate.* Two parts of ferric dimethyl

[1] The writers are indebted to Mrs. Theron McCampbell, owner of the Holmdel Grape Farm, Holmdel, N. J., for making blocks of grapes available for this work and furnishing the equipment, labor, and some of the materials for the sprays. They are also indebted to G. W. Still, of the Bureau's laboratory at Sandusky, Ohio, for suggestions on conducting experiments with the grape berry moth. R. D. Chisholm and L. Koblitsky, of the Division of Insecticide Investigations, analyzed the sprayed fruit, and L. W. Coles, C. A. Perkins, and H. W. Strabel, of the Bureau's Japanese beetle laboratory, assisted in the biological work.

[2] This material was conditioned by the Micronizer Processing Company, Inc., Moorestown, N. J.

dithiocarbamate (*Fermate*) were micronized with 1 part of DDT. This material was prepared for spraying by adding the fish glue solution at the rate of 1 pint for each 3 pounds and working into a thin paste before adding to the spray tank.

*Lead arsenate.* A standard commercial powdered lead arsenate was used. It was added to bordeaux mixture as the spray tank was being filled.

*Bordeaux mixture.* Granular commercial copper sulfate and high calcium spray lime were used. The materials were mixed by the grower, the quantities per 100 gallons varying from 12 pounds of each in the late dormant spray to 2 pounds of copper sulfate and 3 pounds of lime in the later sprays.

*Fish oil.* Fish oil, classified as light-pressed menhaden oil, was used in some cases as a sticker for lead arsenate. It was added at the rate of 1 pint per 100 gallons when the tank was almost full.

*Summer oil.* A commercial summer-oil emulsion containing 83 per cent by volume of petroleum oil was used as a sticker for DDT and bordeaux mixture, at the rate of 1 quart per 100 gallons, and was added when the tank was almost full.

APPLICATION OF SPRAYS.—In this vineyard it had been the practice to apply about 100 gallons of spray per acre and to drive rapidly down the rows. This procedure resulted in inadequate coverage of the vines, and there is no doubt that this was an important factor in the increase of insect pests and diseases in the vineyard.

In these experiments the sprays were applied at the rate of 250 to 300 gallons per acre with the sprayer moving at 5 to 10 miles per hour. All sprays were applied by means of a covered U-boom, or canopy boom, with 16 nozzles in fixed positions so arranged as to cover both sides and top of the row in one operation. With drapes on front and back, the spray was an all-enveloping fog within the wind-protecting cover. All the nozzles were used in applying the sprays, except the eighth spray in 1946, when only the top nozzles were used to spray the new growth without getting much spray on the fruit.

Nine spray schedules, including bordeaux-lead arsenate, bordeaux-lead arsenate-DDT, bordeaux-DDT, and *Fermate*-DDT, were tested. The composition of the sprays and the time of application in each schedule are outlined in table 1. Schedules 1, 2, and 6 were used in the experimental blocks and throughout the remainder of the vineyard in 1944, 1945, and 1946, respectively; the other schedules were applied to the experimental blocks only and, with the exception noted later, each was applied to a half-acre of each variety of grapes on about 300 vines. Schedule 3 was tested in 1944, schedules 4 and 5 were tested in 1945, and schedules 7, 8, and 9 in 1946. The experimental schedules were developed by a trial-and-error process, and there has not been an opportunity to test all of them simultaneously. It is realized that the variation in the density of the insect populations from season to season is an uncorrected factor, but it is of minor importance in the light of the extreme differences in control obtained with the different materials.

ARRANGEMENT OF EXPERIMENTAL BLOCKS.—In 1944 the blocks of Muscat and Niagara grapes were divided at the middle of the rows into two equal units. Schedule 1 was applied to the northern half of the Muscat block and to the southern half of the Niagara block; schedule 3 was applied to the other portions of these blocks. In 1945 and 1946 treatments were applied to single rows, replicated six times. The varieties Delaware, Muscat, and Niagara were included.

This vineyard includes a 1-acre block formerly used for display purposes, containing the following varieties of grapes:

| | |
|---|---|
| Brighton | Martha |
| Brilliant | Missouri Riesling |
| Butler | Muscat |
| Caco | Niagara |
| Catawba | Ontario |
| Champion | Perkins |
| Clinton | Pocklington |
| Concord | Portland |
| Cottage | Regal |
| Etta | Salem |
| Fredonia | Sheridan |
| Herbert | Telegraph |
| Hungarian | Urbana |
| Iona | Vergennes |
| Janesville | Wilder |
| Lindley | Woodruff Red |
| Lutie | Worden |

In 1943 this block was so heavily infested with grape berry moths and Japanese beetles and so badly infected with black rot as to be a menace to adjacent block and was to be eliminated. It presented an unusual opportunity for a study of the

reaction of the different varieties to the sprays and of the influence of the variety on the control of the grape berry moth and the Japanese beetle. This block was sprayed with schedule 3 in 1944, with schedule 5 in 1945, and with schedule 7 in 1946.

of a sprayed leaf, and prepare their cocoons without being killed by the arsenical. Shortly before harvest the vines receiving five applications of lead arsenate had 44.8 per cent of the berries infested, and those receiving six applications 24.2 per cent. The actual damage was even

**Table 1.—Composition and timing of sprays used in grapes.**

| Spray No. | Time | Composition of 100 Gallons of Spray in the Following Schedules | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 2 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | Late dormant | 12-12 B | 12-12 B | 12-12 B | 1 DDT 12-12 BE | 1 DDT 2 FE | 12-12 BE | 12-12 BE | 12-12 BE | 12-12BE |
| 2 | Growth 0.5 inch | 8-12 B | 3 Pb 8-12 B | 8-12 B | — | — | 12-12 BE | 12-12 BE | 12-12 BE | 12-12 BE |
| 3 | Cluster break | 4 Pb 6-12 B | 3 Pb 8-12 B | 4 Pb 6-12 B | 1 DDT 6-12 BE | 1 DDT 2 FE | 6-12 B[1] | 6-12 B | 6-12 B | 6-12 B |
| 4 | Pre-blossom | 4 Pb 6-12 BO | 3 Pb 6-12 B | 4 Pb 4-12 B | — | — | 1 DDT 2-3 B | 1 DDT 2-3 B | ½ DDT 2-3 B | ½ DDT 2-3 B |
| 5 | Petal fall | 4 Pb 6-12 BO | 3 Pb 6-12 B | 1 DDT 6-12 BE | 1 DDT 6-12 BE | 1 DDT 2 FE | 1 DDT 2-3 B | 1 DDT 2-3 B | ½ DDT 2-3 B | ½ DDT 2-3 B |
| 6 | Pea stage | 4 Pb 6-12 BO | 3 Pb 6-12 B | 6-12 B | — | — | 1 DDT 3-6 B | 1 DDT 3-6 B | ½ DDT 2-3 B | ½ DDT 2-3 B |
| 7 | 7–10 days after pea stage | 4 Pb 6-12 BO | 3 Pb 4-10 B | 1 DDT 6-12 BE | 1 DDT 4-10 BE | 1 DDT 2 FE | 1 DDT 3-6 B | — | — | — |
| 8 | 2–3 weeks after pea stage | 6-12 B | 4-10 B | 1 DDT 6-12 BE | 1 DDT 4-10 BE | 1 DDT | ½ DDT | ½ DDT | 1 DDT | ½ DDT |

B = Bordeaux mixtures
BE = Bordeaux mixtures + 2 pt. summer-oil emulsion
BO = Bordeaux mixtures + 1 pt. menhaden oil
½ DDT = 8 oz. DDT
¾ DDT = 12 oz. DDT
1 DDT = 1 lb. DDT
2 FE = 2 lb. *Fermate* + 2 pt. summer-oil emulsion
3 Pb = 3 lb. lead arsenate
4 Pb = 4 lb. lead arsenate

[1] 8 ounces of DDT was added to this spray to eliminate a heavy infestation of leafhoppers in those blocks which had no DDT in previous seasons.

CONTROL OF GRAPE BERRY MOTH.—The degree of control obtained by sprays directed against the first brood of berry moth larvae was determined shortly before harvest by counting uninfested and infested berries on bunches selected at random throughout the experimental blocks. In each block of Delaware, Muscat, or Niagara grapes 250 bunches were examined in 1944 and 300 subsequently; in the block of mixed varieties 1130 bunches were examined. Since there seemed to be no consistent differences between varieties, and since the varieties used were the same for all treatments to be compared directly, only the totals are given in the summary of results in table 2.

Schedules of five or six bordeaux-lead arsenate sprays directed against the first brood (schedules 1 and 2) were inadequate to control the grape berry moth. In July it was common to find cocoons on leaves with visible spray residue, which showed that the larvae were able to crawl over a sprayed surface, cut a small portion

greater than indicated by these figures because most of the berries attacked by the first brood had fallen earlier.

**Table 2.—Effectiveness of bordeaux-lead arsenate, bordeaux-lead arsenate-DDT, bordeaux-DDT, and *Fermate*-DDT sprays in controlling the grape berry moth, Holmdel, N. J., 1944–1946.[1]**

| Spray Material | Schedule | | Per Cent of Berries Infested |
|---|---|---|---|
| Bordeaux-lead arsenate | 1 | 1944 | 44.8 |
| | 2 | 1945 | 24.2 |
| Bordeaux-lead arsenate-DDT | 3 | 1944 | 21.7 |
| Bordeaux-DDT | 4 | 1945 | 11.8 |
| | 6 | 1946 | .01 |
| | 7 | 1946 | .16 |
| | 8 | 1946 | .01 |
| | 9 | 1946 | .04 |
| *Fermate*-DDT | 5 | 1945 | 10.0 |

[1] All schedules were used in blocks of Delaware, Muscat, and Niagara grapes except schedule 7, which was used in the block of mixed varieties.

The substitution of DDT for lead arsenate in the fifth and seventh applications (schedule 3) reduced the infestation at harvest by half, although one-third of the berries were infested at the time these applications were made. Most of these berries dropped within a few weeks, and were not recorded at harvest time.

In 1945 some improvement in control resulted from the use of DDT, 1 pound per 100 gallons, in the first and third sprays before the first brood appeared as well as in the fifth and seventh sprays when this brood was attacking the clusters (schedules 4 and 5). Since summer oil was added as a sticker, the preblossom and pea-stage sprays were omitted to avoid excessive residue. This experiment demonstrated that an adequate protective coating could not be built up before the first brood appeared. When DDT was omitted from the preblossom and pea-stage sprays, the protection given the blossoms and fruit during this critical period was apparently insufficient, since the treatment permitted 10 to 12 per cent of the fruit to become wormy.

In 1946 practically complete elimination of the grape berry moth was obtained with three or four DDT sprays, applied during the period from just before blossoming to and including the early development of the berries (schedules 6 to 9). No larvae were observed in the blossoms, and no cocoons were found on the leaves throughout the summer. Equally good results were obtained with 8 ounces (schedule 9) as with 1 pound of DDT (schedule 6), but in order to have an ample margin of safety it would seem advisable to use not less than 1 pound per 100 gallons of spray.

Three DDT sprays applied just before blossoming and during the early development of the berries (schedule 7) gave good protection throughout the variety block. No marked differences in the control on the different varieties occurred. In no instance was as much as 1 per cent of the berries infested.

CONTROL OF JAPANESE BEETLE.—The Japanese beetle usually appears in the vineyard early in July, is most abundant late in July, and remains in diminishing numbers until frost. The beetle attacks the foliage on the upper part of the vines, working downward as the leaves are partially or wholly skeletonized. It is particularly fond of the fruit of early-ripening varieties, such as Niagara, Ontario, and Portland. However, the fruit of all varieties is subject to attack, especially when infested with the grape berry moth or infected with black rot. Beetles attack this damaged fruit and then begin to feed on the adjacent undamaged berries. The secret of Japanese beetle control is to prevent them from becoming established in large numbers on the vines.

Five or six lead arsenate sprays, applied before July 1 as in schedules 1 and 2, did not protect the foliage and fruit from attack by the beetles. They became established on the new unsprayed growth and then fed on the developing berries, particularly on the early-ripening varieties and on those infested with the grape berry moth or infected by black rot. It was not desirable to apply another arsenical spray in mid-summer because of the hazard of building up excessive residue on the fruit.

Three sprays, containing 8 ounces to 1 pound of DDT per 100 gallons, applied late in May and throughout June just before blossoming and during the early development of the berries, protected the vines from attack until mid-July. Many beetles were killed without feeding by coming into contact with the sprayed foliage. Then, when the beetles were beginning to become established on the new unsprayed foliage, a spray containing 8 ounces of DDT per 100 gallons was applied. In applying this spray in mid-July it is essential that the outer foliage be thoroughly covered. To avoid increasing the residue appreciably on the fruit it is desirable not to drive the spray through the mass of leaves. This spray was therefore applied from above the vines, only the top nozzles on the U-boom being used. The DDT spray applied in mid-July destroyed a large number of the beetles on the vines and protected the fruit of all varieties and the foliage of most of them for the remainder of the summer.

Adequate protection of the foliage was obtained with these DDT sprays on all varieties, with one exception. Only an occasional beetle and a few random punctures on the upper leaves were observed on the varieties Butler, Caco, Catawba, Champion, Concord, Cottage, Delaware, Etta, Fredonia, Herbert, Iona, Janesville, Lindley, Martha, Missouri

Riesling, Muscat, Niagara, Ontario, Perkins, Pocklington, Portland, Regal, Salem, Sheridan, Telegraph, Wilder, Woodruff Red, or Worden. On Brighton, Brilliant, Clinton, Lutie, Urbana, and Vergennes the feeding was more generally distributed and occasionally a partially skeletonized leaf was found. Hungarian was the only variety on which the DDT sprays did not prevent rather extensive feeding. This rapidly growing variety with small, hairy leaves was very attractive to the beetles and rather difficult to wet properly with the sprays. Fortunately, Hungarian grapes seem to be of little economic importance and few are grown in this area.

EFFECT OF DDT SPRAYS ON OTHER INSECTS.—The rose chafer, *Macrodactylus subspinosus* (F.), sometimes causes severe damage to foliage, blossoms, and newly set berries, but it has not been a serious problem in this vineyard, Several dead and dying rose chafers were found beneath the vines after the application of 8 ounces of DDT in the preblossom, petal-fall, and pea-stage sprays, indicating that this insect could be controlled by these sprays.

When lead arsenate was used for the control of the grape berry moth, the grape leafhoppers, *Erythroneura* spp., were usually abundant during August in this vineyard. In May 1946 a heavy infestation developed in blocks sprayed in previous years with lead arsenate. As this was before the time scheduled for the first DDT spray against the grape berry moth, 8 ounces of DDT was added to each 100 gallons of bordeaux and used in these blocks. Within 10 days all the leafhoppers had disappeared. In other sections of the vineyard where DDT had been used the previous year, no leafhoppers appeared. It was evident that, when DDT is used for the control of the grape berry moth and the Japanese beetle, leafhoppers are practically eliminated.

The grapevine aphid, *Aphis illinoisensis* Shimer, was found often during the summer on young shoots and leaves of vines sprayed with DDT, but was never sufficiently numerous to cause damage. Spraying with DDT in strengths up to 1 pound per 100 gallons caused no significant change in the population of aphids.

The grape mealybug *Pseudococcus maritimus* (Ehrh.) has occurred in this vineyard in small scattered infestations for several years. Spraying with DDT seemed to have little effect on this insect.

During the summer many lacewing flies, the larvae of which feed on aphids, were found throughout the vineyard. DDT seemed to have no effect on them unless they were hit by the spray.

Only a few honeybees, were observed in the vineyard at the time of blossoming and occasionally throughout the summer. Except when hit by the spray the bees seemed to be unaffected by DDT.

Mites of various species have usually become abundant on their host plants after being sprayed with DDT. However, no mites were found on the grapes sprayed with DDT in these tests.

In 1946 the leaves, tendrils, and stalks of the fruit clusters on a few vines sprayed with DDT were found infested with the grapevine tomato gall, caused by *Lasioptera vitis* O.S. It was evident that the deposit of DDT on the vines did not protect them from attack by this midge.

EFFECT OF DDT ON THE VINES.—No injury to the fruit or foliage of any of the 35 varieties of grapes was observed after the application of five DDT sprays. When *Fermate* was used as a fungicide in place of bordeaux mixture, the leaves on the vines tended to be larger and greener.

With three sprays against the grape berry moth and one against the Japanese beetle, it was estimated that 315 pounds of DDT would be applied annually per acre. There was a question whether the accumulation of DDT in the soil might ultimately be detrimental to the vines. Cuttings of the varieties Delaware and Fredonia were therefore set in soil treated with DDT at the rates of 25 and 50 pounds per acre. They rooted and the plants developed normally. With these sprays more than 14 years would be required for the accumulation of 50 pounds of DDT in the soil. The indications are that the accumulation of DDT in the soil is not a hazard to the life of the vineyard.

SPRAY RESIDUE ON THE BERRIES.—The residues on the fruit sprayed with DDT-*Fermate* were less conspicuous than those on fruit sprayed with DDT-bordeaux or DDT-lead arsenate, but the grower considered the black deposit on the fruit to be very objectionable. In any spraying program for the control of insects on grapes, it is important to consider the amount of toxic residue on the fruit at

harvest. Bunches of grapes were picked at random 2 to 4 weeks before harvest and analyzed. Table 3 shows the results.

When a spray containing 3 pounds of lead arsenate per 100 gallons was applied six times before July 1, the $As_2O_3$ residue on the berries averaged 4.2 p.p.m.

When DDT was used at the rate of 1 pound per 100 gallons in 4 sprays applied before July and at 8 ounces per 100 gallons in July (schedule 6), the DDT residue on the fruit was 4.3 p.p.m. However, when summer oil was added as a sticker, as in schedules 4 and 5, the DDT residues were 9.0 and 18.4 p.p.m., respectively.

The DDT residues on the fruit receiving three sprays containing 16, 12, or 8 ounces of DDT, applied before July, and one spray with 8 ounces per 100 gallons in July were 3.8, 3.2, and 2.7 p.p.m., respectively (schedules 7, 8, and 9).

CONTROL OF BLACK ROT.—The control of black rot was not within the scope of this investigation and was conducted by the grower. It was evident, however, that sanitation, more thorough spraying, and timing were factors in bringing this disease under control. In 1943 black rot was prevalent throughout the vineyard; in 1944 and 1945 it was progressively less prevalent, and in 1946 it was practically non-existent in the vineyard.

SUMMARY.—Spraying with lead arsenate was inadequate for control of the grape berry moth, *Polychrosis viteana* (Clem.), and the Japanese beetle, *Popillia japonica* Newm., in an isolated 70-acre commercial vineyard in New Jersey. Experiments with DDT over a 3-year period demonstrated that three sprays containing 1 pound of DDT with 100 gallons of bordeaux mixture, applied just before blossoming, at petal fall, and when the grapes were the size of peas, controlled the grape berry moth. These sprays protected the vines from attack by the beetles until mid-July. An additional spray containing 8 ounces of DDT per 100 gallons protected the fruit and foliage from the beetle for the remainder of the season.

The DDT sprays used also controlled the rose chafer, *Macrodactylus subspinosus* (F.), and the grape leafhoppers, *Erythroneura* spp., but had little effect on the grapevine aphid, *Aphis illinoisensis* Shimer, the grape mealybug, *Pseudococcus maritimus* (Ehrh.), or the grapevine tomato gall caused by *Lasioptera vitis* O.S. Mites did not occur in this vineyard.

The DDT sprays did not injure the fruit or foliage, and the indications are that residues from these sprays accumulating in the soil would not be a hazard to the life of the vines.

DDT residues on the grapes 2 to 4 weeks before harvest were well below 7 p.p.m. when no oil was used and above 7 p.p.m. when oil was used as a sticker.—6-26-47.

**Table 3.—Residues 2 to 4 weeks before harvest on several varieties of grapes sprayed with lead arsenate or DDT.**

| INSECTICIDE AND SCHEDULE No. | RESIDUES, p.p.m | | | |
|---|---|---|---|---|
| | Muscat | Niagara | Concord | Fredonia |
| | Lead arsenate | | | |
| 2 | 4.5 | 3.9 | — | — |
| DDT | | | | |
| 4 | 7.6 | 10.3 | — | — |
| 5 | 17.6 | 19.1 | — | — |
| 6 | 3.9 | 4.7 | 5.5 | 3.2 |
| 7 | — | — | 3.8 | — |
| 8 | 2.9 | 3.5 | — | — |
| 9 | 2.6 | 2.8 | — | — |

# Soil Treatment for Wireworms and Cutworms[1]

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Wireworms are frequently reported as agricultural crop pests in various sections of North Carolina. Injury to row crops such as tobacco and corn is particularly noticeable because of the necessity of replanting in the case of tobacco and reseeding in the case of corn. Cutworms are even more spectacular in the damage they do to row crops than are wireworms. In North Carolina, cutworm injury has been severe in nearly all parts of the state.

The principal cutworm causing injury to corn seedlings in the Wilmington area is *Agrotis ypsilon* (Rott.). This cutworm, in its younger stages, is responsible for cutting seedlings above the soil surface whereas the full-grown forms of the same species usually stay under the soil surface and cut the seedlings either below or just at the surface.

There are several species of wireworms infesting corn fields but the wireworms responsible for most of the damage are *Conoderus bellus* (Say) and *C. auritus* (Herbst). Germinating seed may be completely riddled or the young seedlings may be damaged by the larvae boring through the stems just below the soil surface. This damage causes withering of the plant and eventually the plant may die. Older plants, growing vigorously, may overcome this type of damage. Undoubtedly, there must be considerable feeding by elaterid larvae in the roots of corn plants but it was not possible to check on this type of feeding in the field.

On one farm in the Wilmington area, the combined attacks of wireworms and cutworms in the same field have materially reduced the yield of corn. Despite the planting of double the usual amount of seed, only half a stand came through to maturity because of the feeding of wireworms on corn seed or the ravenous feeding of cutworms on seedling corn.

In order to determine the effectiveness of various soil insecticides for the control of these pests, experiments were planned whereby both pests might be controlled by one treatment with a soil insecticide.

METHODS AND MATERIALS.—In the first experiment, the soil was treated with DDT, or benzene hexachloride, or dichloropropane-dichloropropene immediately before or after the planting of corn. Three formulations of DDT were used: (1) a wettable powder containing 50 per cent DDT; (2) a 50 per cent DDT dust concentrate;[3] and (3) a 10 per cent DDT dust.[4] Benzene hexachloride was used as a dust and as a water suspension. Dichloropropane-dichloropropene,[5] although reported and unsafe for use on growing crops, was used in order to determine its effect on the germination of seed.

These materials were used at various amounts per acre on plots consisting of 11 feet of row, in a strip 2 feet wide (*i.e.*, 1 foot on either side of the row of corn). The dust materials were broadcast over the plots and then mixed with the top 2 inches of soil before the corn was planted. The liquid formulations were applied to the plots immediately after the corn was planted. All corn was planted with a machine and seeded in rows 42 inches wide and 8 inches apart in the rows.

The insecticides and the rates at which they were used are listed in table 1. All plots were examined within 30 minutes after treatment in order to observe any immediate effect of the treatments on wireworms and cutworms. A second examination was made 3 weeks after treatment.

In the second experiment, concentrated DDT dust, diluted with sand to a mixture containing 5 per cent DDT, was applied directly to the soil surface at a distance of 1 to 2 inches from the rows of seedling corn. This mixture was applied in a band 2 inches wide by means of a fertilizer distributor of the type commonly used to side-dress row crops. The material was applied close to the rows of seedling corn because the greatest number of wireworms and cutworms were found in the rows. It was thought that DDT applied in this region would give the greatest

[1] Contribution from the Department of Zoology and Entomology, North Carolina Agricultural Experiment Station. Published with the approval of the Director as Paper No. 264 of the Journal Series.

[2] Assistant Professor, Department of Zoology and Entomology.

[3] Both supplied by the Pennsylvania Salt Manufacturing Co.

[4] (*Neocid*, supplied by the Geigy Co.)

[5] (Commonly termed D-D and supplied by the Shell Development Co.

amount of control. The DDT dust concentrate was mixed with sand because such a mixture was easier to apply with the fertilizer distributor than a DDT-pyrophyllite dust. Furthermore, the DDT-sand mixture was not as easily blown about by the wind in the process of being laid down by the distributor as was a DDT-pyrophyllite dust.

The 5 per cent DDT-sand mixture was applied at the rate of 500 pounds to the acre which was the equivalent of 25 pounds of technical grade DDT per acre. An area of 3 acres was treated in this second experiment.

RESULTS.—In the first test, an examination of the area of the plots before treatment showed an average wireworm population of 11 wireworms per cubic foot of soil. Most of these were in the upper 3 inches of soil. This estimate was based on a random sampling of the test area. Ten samples, 6 inches by 6 inches to a depth of 6 inches, were taken on each diagonal of the test area. The soil in each sample was sifted through a sieve made of quarter-inch mesh wire screen into another sieve made of wire screen cloth of 14 meshes to the inch. Any wireworms seen in this first sifting were collected. The soil in the 14-mesh screen sieve was again sifted and carefully inspected, especially for smaller wireworms.

With the exception of the plot treated with 1 per cent benzene hexachloride in a water suspension, there was no activity of wireworms or cutworms observed immediately after treatment. This does not necessarily mean that the other treatments were not toxic to soil insects. It is possible that some of the other treatments may have caused the death of some soil pests before these could reach the soil surface.

In one of the benzene hexachloride-treated plots (200 pounds of 1 per cent benzene hexachloride, per acre as a water suspension) there was a reaction to the treatment within 5 minutes. At least 5 cutworms, *Agrotis ypsilon*, came to the surface of the soil as did several wireworms and click beetles, *Conoderus* spp., flies, and ground beetles. Of these insects only one wireworm was alive 2 hours after treatment. On the day following treatment, no additional insect activity or mortality was observed.

Three weeks after treatment, the plots were examined to observe the effect of the insecticides on seed germination and the efficiency in protecting corn from wireworm and cutworm attack. A total of 17 plants per plot indicated a 100 per cent germination of planted seed and evident protection from wireworms and cutworms. The results of this examination are listed in table 1.

These results, although by no means conclusive, give some indication as to what degree of protection may be afforded

**Table 1.—Number of plants in plots 3 weeks after treatment.**

| MATERIAL | POUNDS OF MATERIAL PER ACRE | POUNDS OF ACTIVE INGREDIENT PER ACRE | NUMBER OF PLANTS PER PLOT |
|---|---|---|---|
| DDT 50% dust | 50 | 25 | 9 |
| | 100 | 50 | 13 |
| | 200 | 100 | 9 |
| | 400 | 200 | 8 |
| Untreated check | | | |
| DDT 10% dust | 10 | 1 | 12 |
| | 25 | 2.5 | 17 |
| | 50 | 5 | 11 |
| | 100 | 10 | 12 |
| Untreated check | | | |
| Benzene hexachloride dust—1% gamma isomer | 100 | 1 | 6 |
| | 200 | 2 | 12 |
| | 500 | 5 | 14 |
| | 1000 | 10 | 10 |
| Untreated check | | | |
| Benzene hexachloride 1% gamma isomer content wettable powder as a water suspension | 40 | 0.4 | 10 |
| | 80 | 0.8 | 7 |
| | 200 | 2 | 0 |
| | 400 | 4 | 11 |
| Untreated check | | | |
| DDT 50% wettable powder as a water suspension | 40 | 20 | 11 |
| | 80 | 40 | 10 |
| | 200 | 100 | 11 |
| | 400 | 200 | 9 |
| Untreated check | | | |
| Dichloropropane-dichloropropene | 50 | 50 | 5 |
| | 100 | 100 | 0 |
| | 500 | 500 | 0 |
| | 1000 | 1000 | 7 |
| Untreated check | | | 6 |

by the use of these materials. There were more plants in the 10 per cent DDT-treated plots 3 weeks after treatment than in any of the other plots. Greater applications of DDT per acre were apparently no more advantageous than the lower rates of application. A definite retardation of plant growth was noted in the plots treated with the wettable form of DDT at the 200 and 400 pounds per acre applications. Seed treated with these heavy per acre concentrations failed to germinate as rapidly as that treated with the more dilute concentrations. Consequently, plant growth in the plots treated with 200 and 400 pounds of DDT per acre was not as good as it was in plots treated with 40 and 80 pounds of DDT per acre.

Benzene hexachloride was not more effective than the DDT formulations used in this first test. The dust form of benzene hexachloride did not materially affect the germination of corn whereas the wettable form did in some cases very noticeably retard the germination.

Over 70 per cent failure of germination was observed in the dichloropropane-dichloropropene plots.

In the second test, an examination of the treated area 3 hours after treatment showed that the DDT was having some effect on insects. Ground beetles were found lying on their backs incapable of any coordinated movements. Click beetles were still capable of coordinated movements 3 hours after treatment. In 100 lineal feet of row, 4 cutworms, *Agrotis ypsilon*, were observed. These appeared to be sluggish and not normal in their movements. The next morning, 15 hours after treatment, these cutworms as well as several ground beetles, crickets, and grasshoppers were found dead.

*Agrotis ypsilon*, in its older stages, was seemingly not affected by DDT applied to the soil surface, probably because the older larvae did not crawl over the soil surface extensively enough to pick up a lethal dose of DDT. The younger larvae did crawl over the soil surface more than the older ones did and, in turn, were probably affected by lesser amounts of DDT.

There was evidently no control of wireworms due to the surface application of the 5 per cent DDT-sand mixture.

DISCUSSION.—The experimental field was characterized by 2 types of soil—a sandy loam and a sand. Each type occupied an area equal to about half the field. Wireworm and cutworm attacks were confined to the sandy loam type of soil. Cutworm attacks were particularly severe along a wide ditch bank bordering the sandy loam portion of the field.

Wireworm damage in the sandy loam part of the field seemed to be about evenly distributed over this part of the field. Wireworms were usually more abundant in the upper layers of the soil, becoming less abundant at 3 to 6 inches below the soil surface. The number of wireworms in the upper 3 inches of soil from mid-April to mid-May was 50 per cent greater than the number at a depth of 3 to 6 inches below the soil surface. Thus, the number of wireworms in the upper 3 inches of soil was evidently correlated with the amount of damage done to seed and seedling corn.

The number of wireworms per acre in the sandy loam section of the field was estimated at about 250,000. This estimate was based on random sampling taken on both diagonals of the field. Such a dense population can well be expected to cause considerable damage to row crops. Roebuck (1924) estimated that a population of 200,000 wireworms, *Agriotes lineatus* and *A. obscurus*, per acre was the utmost limit of safety regarding damage to row crops. Hawkins (1936) found severe damage to potato tubers when the wireworm, *Agriotes mancus* Say, population was 91,000 to 100,000 per acre. Tenhet & Howe (1939) reported severe damage to row crops by the sand wireworm, *Horistonotus uhlerii* Horn, at an estimated population of 20,000 larvae per acre.

It is well known that DDT and benzene hexachloride are destructive to soil micro-organisms, some of which may be beneficial to plant growth. The degree of toxicity to various micro-organisms in different types of soil has not as yet been fully determined. The residual effect of these insecticides in the soil and the effects on different species of plants is not yet fully understood. Until a more complete knowledge of these important problems is acquired, it is recommended that DDT and benzene hexachloride be used with caution when applied to the soil for the control of subterranean insect pests.

SUMMARY.—Cutworms, *Agrotis ypsilon* (Rott.) and wireworms, *Conoderus bellus* (Say) and *C. auritus* (Herbst), have been

observed as serious pests of row crops in the Wilmington, North Carolina, area. A DDT-sand mixture, containing 5 per cent DDT and used at the rate of 500 pounds per acre, applied in a narrow strip on either side of seedling corn, afforded some protection from the smaller stages of the cutworms. Neither the older forms of this cutworm, *Agrotis ypsilon* nor the wireworms were controlled by this treatment.

Results of a preliminary test with liquid and dust forms of DDT and benzene hexachloride seemed to indicate that the dust forms of these compounds were safer to use than were the wettable forms. Retardation of seed germination occurred when heavy applications of DDV and benzene hexachloride were made in the form of a dust or a liquid suspension. —7-11-47.

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# Manitoba Honey Flows 1924–1946

A. V. MITCHENER,[1] *The University of Manitoba, Winnipeg, Canada*

A thorough knowledge of the regional and local honey flows is essential if the beekeeper is to manage his apiary to the best advantage. Previous to 1924 very little detailed information was available with respect to the duration and extent of the honey flows in Manitoba. In the spring of that year we began to collect data which would provide this needed information for the beekeepers of this area of North America where many millions of pounds of honey are produced each year.

METHOD.—A number of beekeepers located at widely separated points in Manitoba each volunteered to place an average colony of honey bees upon a set of platform scales at the beginning of May and to record daily the weight of the colony until the end of September. Platform scales large enough to weigh 500 pounds or more were used. As the years have passed, recording personnel and recording stations have changed, but records have been obtained annually for 23 consecutive years. Annual scale colony records have varied from 10 to 19 with a yearly average of 15 for the twenty-three years. Mimeographed instructions, two copies of a printed record form and an addressed stamped return envelope were mailed to each collaborating beekeeper, towards the end of April each year. These were followed towards the end of May, June, July and August respectively each year by additional return envelopes and report forms. Cooperating beekeepers were requested to return their records to the Department of Entomology, The University of Manitoba, Winnipeg, at the end of each month. At the end of each season individual graphs showing each scale colony record were prepared and these were averaged together and a graph made to show the Provincial seasonal honey flow. These seasonal graphs are shown in Figures 1 to 8. Each assisting beekeeper was sent a copy of the graph showing his own scale colony record as well as a copy of the graph showing the average honey flow for Manitoba for that particular year. In preparing all of these graphs the flow was shown for five day periods. This method of showing the flow, smoothed out the very great daily fluctuations due to the varying weather conditions.

RECORDS.—Figures 1 to 4 inclusive show the details of each annual honey flow, from 1924 to 1946 inclusive. The records of three successive years are shown in each figure. The graph showing the honey flow for each year was made by averaging the individual scale colony reports for that year. Figure 4 shows the

[1] The writer is indebted to the many Manitoba beekeepers who over a period of twenty-three years have recorded the daily weight of a scale colony from May to September inclusive for one or many years. From at least three yards records have been submitted for each of the twenty-three years.

five annual flows for 1925–1929 and for 1930–1934 averaged together. Similarly, Figure 4 shows the flows for the two succeeding five year periods, namely, 1935–1939 and 1940–1944.

DISCUSSION.—An examination of each of the 23 annual records shows that there is a single main honey flow (actually nectar flow) in Manitoba each year. In 1925–1929 the flow began during the fourth week of June. During 1930–1934 and 1935–1939 the flow began about five days earlier namely, during the five day period June 19–23. During 1940–1944 the flow began a few days earlier still. Considering the whole twenty year period of honey flow, colonies began to show gains by June 21 or by the longest day of the year.

The change in the duration of the honey flow during the past two decades is a matter of much interest and of great importance to the beekeepers of this area. During 1925–1929 the flow continued strong throughout July and August and ended during the first week of September. Table 1 shows that of the total increase in weight made by the scale colonies during July and August of that period, 52 per cent was made in July and 48 per cent of it was made in August. In 1930 to 1934 of the total increase in scale colony weights in July and August about 64 per cent took place in July and 36 per cent in August. During the 5 year period 1935–1939 of the total July—August increase, July yielded 78 per cent and August 22 per cent. In 1940 to 1944 during the same 2 months 85 per cent of the total increase in colony weight was obtained in July and only 15 per cent in August. It is of interest to note that the total colony gains made during July for each of the last three 5-year periods remained approximately the same.

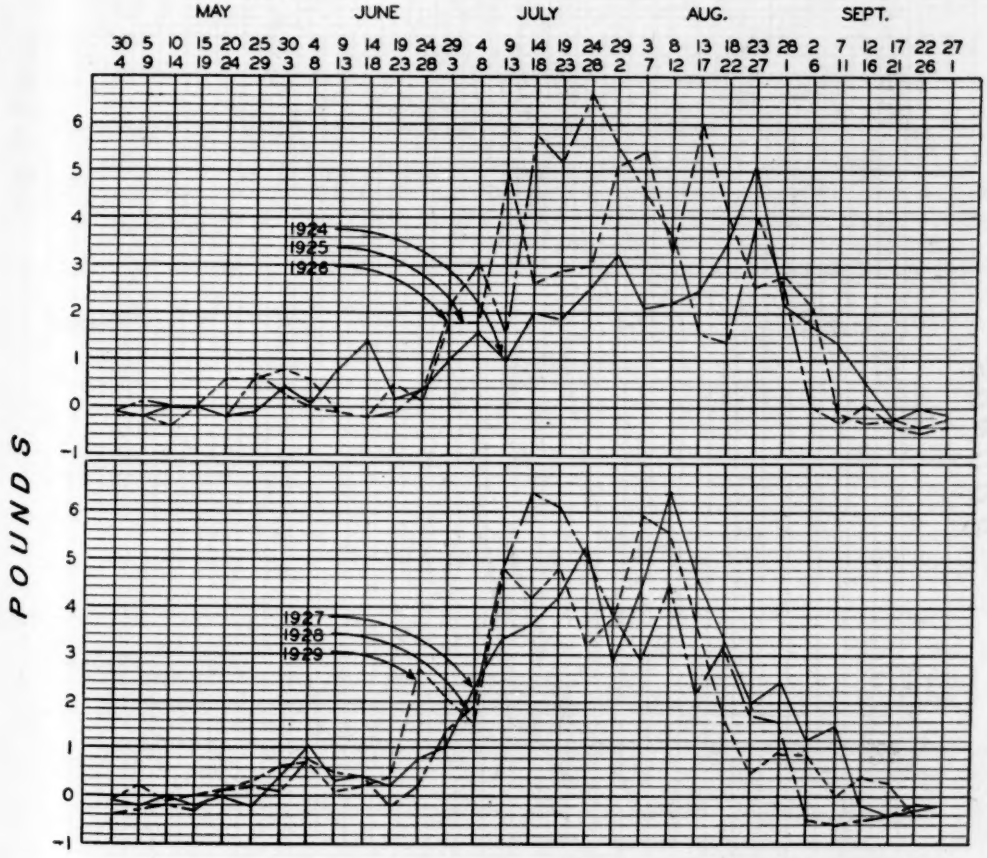


FIG. 1.—Manitoba honey flows; 1924–1929, inclusive.

The decrease in total yield was due almost entirely to the lack of available nectar in the flowers during August.

During the earlier years sweet clover was grown widely in Manitoba for hay. After the hay had been cut the sweet clover grew up again and the new growth was pastured. Fresh bloom appeared continuously in these pastures until frosts came. Honey bees had an excellent source of nectar throughout the summer. Many other fields of sweet clover were allowed to ripen for seed. These also provided much nectar over an extended season. Then sweet clover weevil appeared in 1939 and subsequently the sweet clover acreage has been reduced. More important still is the fact that many farmers now plow down the sweet clover stubble as soon as the hay crop has been removed. Farmers say that the land loses too much moisture if the sweet clover is allowed to grow up again for pasture. It is apparent that Manitoba beekeepers now need some new reliable source of nectar during August.

During the periods 1925 to 1929 and 1930 to 1934 the effective honey flow ceased approximately the first week of September. During 1935 to 1939 very

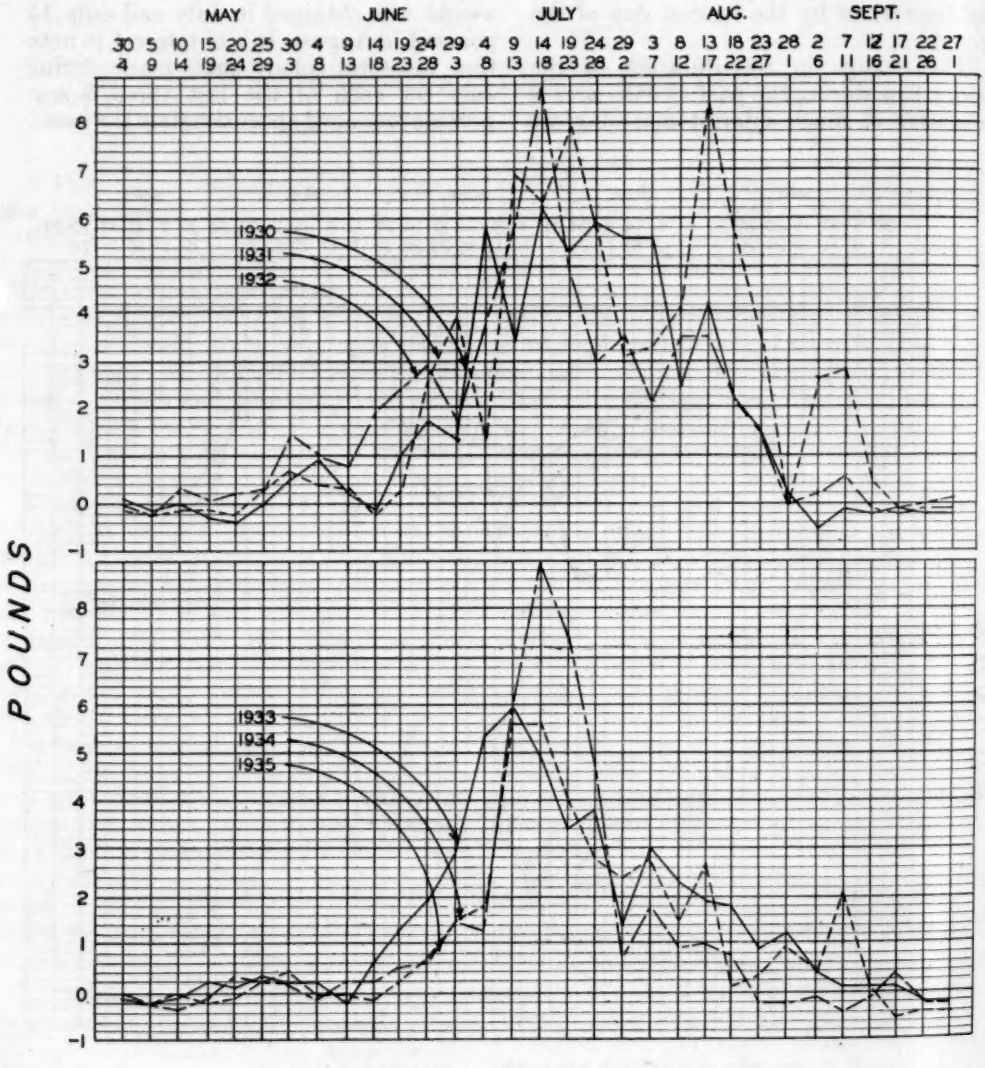


FIG. 2.—Manitoba honey flows; 1930–1935, inclusive.

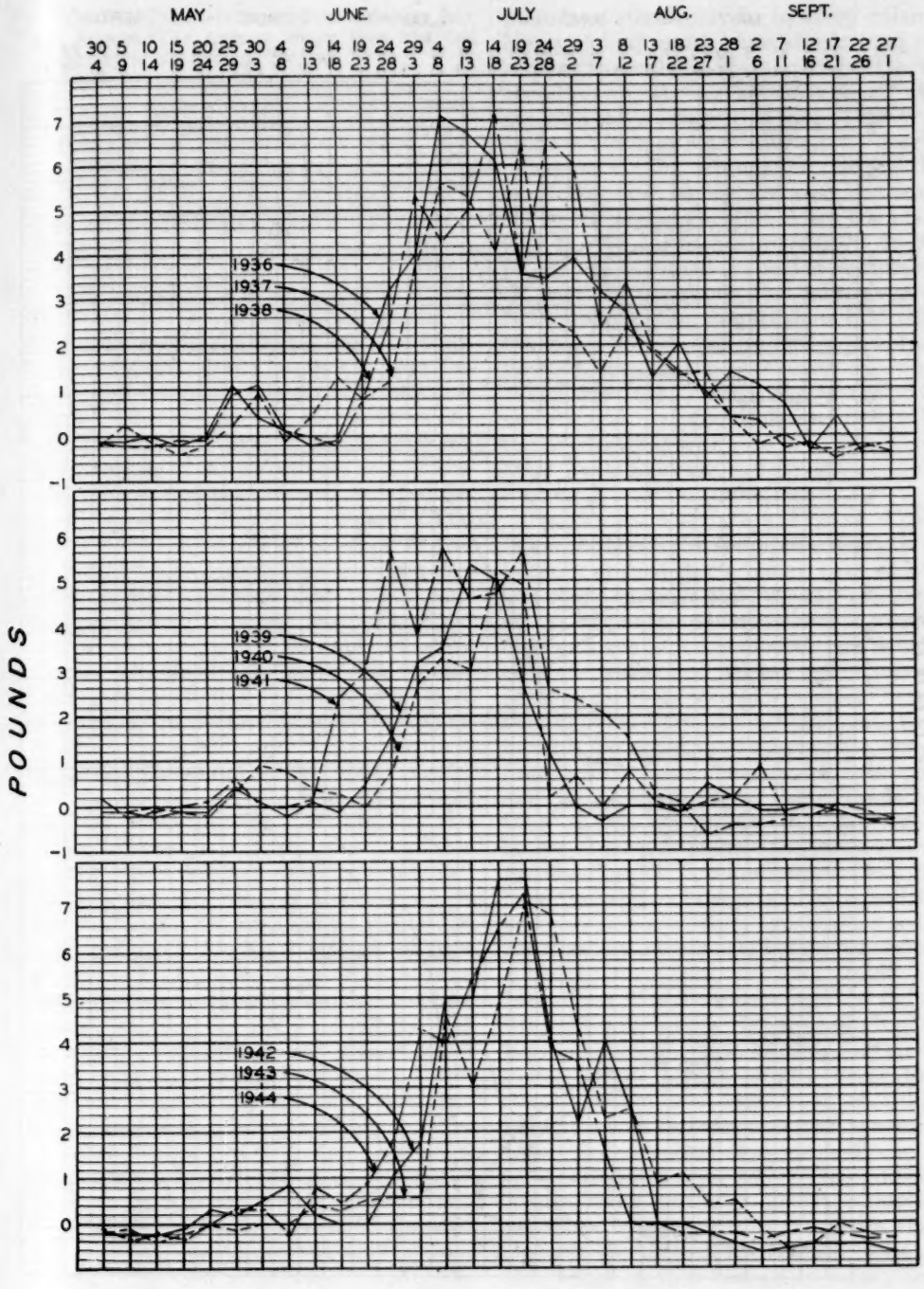


FIG. 3.—Manitoba honey flows; 1936–1944, inclusive.

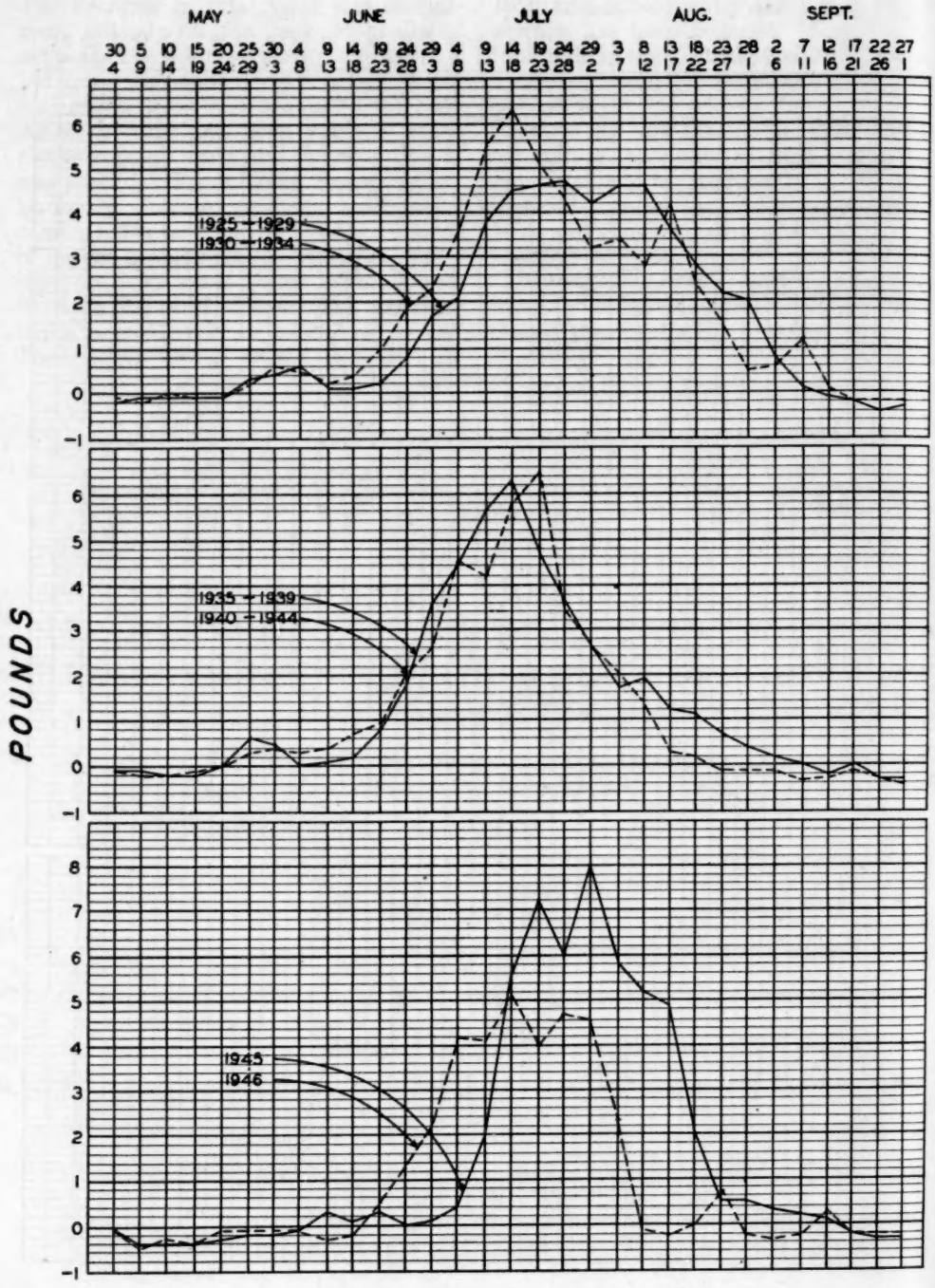


FIG. 4.—Manitoba honey flows; 5-year summaries, 1925–44, and 2-year comparison of 1945 and 1946.

Table 1.—The main honey flow is during July and August. The August honey flow has decreased seriously in recent years.

| FIVE YEAR PERIOD | AVERAGE SCALE COLONY GAIN IN POUNDS | | PERCENTAGE OF JULY–AUG. FLOW | |
|---|---|---|---|---|
| | July | August | July | August |
| 1925–1929 | 116.2 | 105.2 | 52% | 48% |
| 1930–1934 | 140.2 | 80.4 | 64% | 36% |
| 1935–1939 | 142.1 | 39.8 | 78% | 22% |
| 1940–1944 | 138.1 | 23.8 | 85% | 15% |

little gain was made by the scale colonies after August 27 while in 1940 to 1944 the flow had stopped almost entirely by August 12. The end of the flow varied with the individual years, but it is evident from a study of the records for each of the past ten or more years that the end of the flow is coming earlier than formerly. The flow of 1945 is one brighter spot in the picture. The records of the last 10 years (1937 to 1946) indicate that we may expect the effective honey flow now to be over in an average year by approximately August 14. Relatively little crop would have been lost in any year during the past 10 years in an average yard if the apiary had been closed down by August 21. It is possible that some of the honey might still be unripe at that date. There will also be some favored localities in the future where nectar will be available beyond that date. Perhaps a more important date to note is that at which colonies began to lose weight. This has averaged about August 27 during the past 10 years. This might be taken as a basic date for certain manipulations in the apiary. During the period 1930 to 1944 the peak of the honey flow was reached approximately around July 18 at which time the average increase in weight per colony was over 6 pounds daily.

Nearly every year, during the latter part of May and early June, scale colonies show an increase in weight. This is due largely to dandelion bloom. This stimulating flow is very important to the beekeeper. This flow is followed usually before the main flow begins by a dearth of nectar, lasting for from 1 to 2 weeks. At this time beekeepers should see that all colonies have plenty of stores in order that the rate of brood rearing may not be reduced. If colony stores are low, sugar syrup should be fed so that at least 20 pounds of stores may be in every colony. Every colony must have ample food reserves throughout the spring. Heavy brood rearing throughout May sometimes depletes the stores at this time of the year and colonies may starve during this dearth of nectar if they are not fed. Before the dandelion flow begins, colonies lose from 0.1 to 0.2 pound per day. After the main flow is over colonies lose from 0.1 to 0.4 pound per day until the end of September at least. In Manitoba the data given in the accompanying graphs show that once the main flow ceases no new widespread flow of importance has ever followed. When his scale colony shows that the main flow is over the beekeeper may take for granted that with rare local exceptions little further nectar will be gathered by his honey bees that season.

PRACTICAL VALUE OF HONEY FLOW INFORMATION.—In Manitoba many beekeepers destroy their honey bees at the end of the summer and purchase packages at the beginning of the following season. Others attempt to winter their colonies, either in cellars or packed out of doors. Most beekeepers who buy package honey bees purchase two pound packages with queens. To make the best use of a honey flow, colonies should be as strong as possible at the beginning of that flow. It has been shown previously that the main honey flow in Manitoba begins approximately June 21. It takes 3 weeks from the time the worker honey bee egg is laid for it to become a worker. The worker is approximately 3 weeks old before it becomes a fielder honeybee. Working backward from June 21 only those eggs laid before May 10 will become fielder bees by the beginning of the flow. Queens should be laying in the hive a month before that date to provide a large body of fielder honeybees at the beginning of the main honey flow. Package honeybees should be in Manitoba apiaries before the middle of April if their efforts at honey production are to be compared with the yields from overwintered colonies which will be out of the cellars by that time. Any colony that becomes queenless must be requeened at once in the spring if that colony is to build up a maximum working population by the beginning of the honey flow.

Beekeepers who know the approximate period of the honey flow can super their colonies adequately in time to receive all

of the nectar that the honey bees are capable of carrying into the hive. Delay in supering for a few days may result in a greatly reduced honey crop. One scale colony in Manitoba in 1936 made a gain of 66 pounds in a five-day period.

Beekeepers who kill their honeybees at the end of the flow should always kill the queen in each colony about 24 days before they destroy the colonies with cyanogas, in order that no brood may be left to decay in the honeycombs. Previously we have stated that we may use August 27 as a basic date for certain manipulations. If the beekeeper decides that he will kill his honey bees on August 27 he should destroy or remove the queens on August 3. If he does this he will find his combs clean with the possible exception of a few eggs on that date.

It would be of great assistance to beekeepers if queen shippers would mark the top of the thorax of each young queen with a bright color such as yellow before shipping her. It is difficult frequently to locate the queen in populous colonies in early August. The spot of color on the top of the thorax would help very much in locating the queen. If all shippers would use one color in the even numbered years and another specific color in the odd numbered years, beekeepers would know the ages of their queens. If this system were followed beekeepers would know that any unmarked queens in the apiary must have been reared locally.

Some beekeepers who overwinter their honey bees requeen their colonies in the summer with queens which they buy in the south or with queens which they rear in their own apiaries. The best time to introduce a queen is late enough in the summer so that there will be no effect upon the emergence of honeybees that will take a part in gathering the current crop of honey and early enough to get the queen established in the colony so that she will have time to lay many eggs to provide the colony with a maximum of young worker honey bees to go into winter quarters. Again using the basic date of August 27 and remembering that it takes 6 weeks to produce fielder honey bees, it is evident that requeening could be undertaken as early as July 16 without interfering with the issue of workers which would take a part in gathering the current honey crop. However, if colonies are requeened during the first week of August the young queens have sufficient time to populate the colonies with young workers for winter.

SUMMARY.—(1). This paper is based upon the records of a total of 350 colonies of honeybees kept on platform scales for the months of May, June, July, August and September over a period of twenty-three years in Manitoba.

(2). The beginning of the honey flow has advanced about a week during the past two decades.

(3). The average colony gains for July have remained approximately the same since 1930 but August yields have been much reduced.

(4). Manitoba farmers do not grow as much sweet clover as they formerly did and much of what they now grow is managed with less advantage to the beekeeper.

(5). Dandelion bloom in late May and early June provides an important stimulating flow for Manitoba beekeepers.

(6). There is one continuous honey flow in Manitoba beginning approximately June 21, reaching its peak around July 18 and ending approximately August 14.

(7). Manitoba beekeepers should receive and hive their two-pound package honeybees each year before the middle of April.

(8). Beekeepers who intend to destroy their honeybees at the end of the season and who plan to extract around August 27 should kill or remove their queens 24 days earlier, namely, on August 3.

(9). Breeders and shippers of queen honey bees should mark the top of the thorax of each queen with a bright color. Finger nail polish seems to be a satisfactory marking material.

(10). Colonies that are to be wintered may be requeened in Manitoba about the first week of August.—6-20-47.

# Codling Moth and Mite Control in Kansas With New Insecticides[1]

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During the season of 1945 and 1946 the entomological staff of the Northeast Kansas Experiment Fields of the Kansas Agricultural Experiment Station carried on comparative tests of certain insecticide combinations as substitutes and improvements over lead arsenate in spraying for the control of codling moth and the prevention of two-spotted mite infestations. These tests were conducted in Doniphan County at the Blair experiment orchard, Blair, Kansas. The apple variety used in the tests was Jonathan.

INSECTICIDES USED.—*Arsenicals.* Lead arsenate without the addition of a safener or a summer oil emulsion and lead arsenate with zinc sulfate as a safener and summer oil[2] emulsion as a spreader and sticker were used in 1945 and 1946. The summer oil emulsion was omitted after the fifth cover spray in 1945 and after the sixth cover spray in 1946. Lead arsenate plus zinc sulfate and summer oil emulsion was used in the first brood sprays and fixed nicotine[3] plus summer oil emulsion was used in the second brood sprays in one series of tests in 1945.

NEW INSECTICIDES.—Fixed nicotine[3] plus summer oil emulsion was used in 1945 and 1946. In one series of tests in 1945 a fixed nicotine-DDT mixture containing 7 per cent of a 100 per cent soluble nicotine and 17 per cent DDT plus summer oil was used. Two fixed nicotine-DDT combinations were used in 1946. One combination,[4] contained 12 per cent nicotine from a 40 per cent soluble nicotine and 7 per cent DDT plus summer oil emulsion. The other combination,[5] contained 12 per cent nicotine from a 100 per cent soluble nicotine and 7 per cent DDT plus summer oil emulsion.

A 40 per cent DDT[6] was used in one series of tests in 1945 and 50 per cent DDT[7] was used in one series in 1946.

Special mite-killing DDT[7] (16.66 per cent DDT and 20 per cent hydroxypentamethylflavan); di (methoxyphenyl) trichloroethane,[7] a DDT analog; and hexachlorocyclohexane[8] (benzene hexachloride) were used in tests in 1946.

METHODS AND PROCEDURE.—Two single tree replicates were used for each insecticide tested. The replicates were randomized in a block in rows containing ten trees each to obtain as nearly uniform conditions as possible.

A series of bait traps were used each year to provide information as to the proper date for each of the cover sprays. Eight cover sprays were applied to all plots in 1945 and nine cover sprays were applied to all plots in 1946 except the DDT, Mite-Killing DDT and hexachlorocyclohexane plots. These plots received only the first seven cover sprays. Lead arsenate was applied uniformly to all trees in all plots in the calyx spray in 1945 and 1946.

In recording the data from injured fruits, multiple stings or larvae in a single fruit were not considered. When a fruit had both stings and larvae present, it was recorded as "wormy."

To prevent excessive fruit drop, one hormone spray application of naphthalene acetic acid was applied to the trees in the spray plots in 1945. Two hormone spray applications of naphthalene acetic acid were applied to the trees in the spray plots in 1946.

At harvest time samples from all plots were collected and analyzed for arsenic, DMT, or DDT residue.

SEASONAL CONDITIONS AND CODLING MOTH ABUNDANCE.—The weather conditions in 1945 and 1946 were favorable for good plant growth. Cool nights and plentiful rains occurred during much of the spring and summer of 1945. Temperatures and rainfall were moderate in 1946 and characterized an ideal year for codling moth development. Two broods of codling moth occurred in 1945. Codling

Richmond Program.

[1] Contribution No. 551, Department of Entomology.

[2] *Superla.*

[3] *Black Leaf 155* supplied by the Tobacco By-Products Corporation, Louisville, Kentucky.

[4] *Black Leaf 155X.*

[5] *Black Leaf 155Y.*

[6] Furnished by the Geigy Company, Inc., New York (Gesarol AK40 Spray).

[7] Furnished by the E. I. duPont de Nemours and Co., Inc., Wilmington, Delaware.

[8] Supplied by the Commercial Solvents Corporation, New York, New York.

**Table 1.—Insecticides, dosages, and schedules used in control tests in pounds per 100 gallons of spray mixture.**

| TREATMENT: ALL PLOTS HAD A CALYX SPRAY OF LEAD ARSENATE, 4 LBS. | |
|---|---|
| 1945 | 1946 |
| 1. Lead arsenate, 4 lbs. | 1. Lead arsenate, 4 lbs. |
| 2. Lead arsenate, 4 lbs. plus zinc sulfate, 4 ozs. plus oil emulsion,[1] 1 qt. Oil omitted after 5th cover. | 2. Lead arsenate, 4 lbs. plus zinc sulfate, 4 ozs. plus oil emulsion,[1] 1 qt. Oil omitted after 6th cover. |
| 3. Lead arsenate, 4 lbs. plus zinc sulfate, 4 ozs. plus oil emulsion,[1] 1 qt., 1st brood; *Black Leaf 155*, 2 lbs. plus oil emulsion, 2 qts., 2nd brood. | 3. Not used in 1946. |
| 4. *Black Leaf 155*, 3 lbs., 1st cover; *Black Leaf 155*, 2 lbs., plus oil emulsion,[1] 2 qts., 2nd through 5th covers; *Black Leaf 155*, 2 lbs., plus oil, 3 pints, 6th through 8th covers. | 4. *Black Leaf 155*, 3 lbs., 1st and 2nd covers; *Black Leaf 155*, 2 lbs. plus oil emulsion,[1] 1 qt., 3rd through 9th covers. |
| 5. Not used in 1945. | 5. *Black Leaf 155X* (12% from 40% soluble nicotine plus 7% DDT), 3 lbs., 1st and 2nd covers; *Black Leaf 155X*, 2 lbs., plus oil emulsion,[1] 1 qt., 3rd through 9th cover. |
| 6. *Black Leaf 155*-DDT (7% from 100% soluble nicotine plus 17% DDT), 3 lbs., 1st cover; *Black Leaf 155*-DDT, 2 lbs. plus oil emulsion,[1] 2 qts., 2nd through 5th cover sprays; *Black Leaf 155*-DDT, 2 lbs. plus oil, 3 pints, 6th through 8th covers. | 6. *Black Leaf 155Y* (12% from 100% soluble nicotine plus 7% DDT), 3 lbs., 1st and 2nd covers; *Black Leaf 155Y*, 2 lbs., plus oil[1] emulsion, 1 qt., 3rd through 9th cover. |
| 7. 40% DDT spray, 1 lb. (8 ounces DDT). | 7. 50% DDT, 2 lbs. (1 lb. DDT), 1st through 7th covers |
| 8. Not used in 1945. | 8. Mite-killing DDT, 5 lbs. (16.66% DDT, 20% hydroxypentamethylflavan), 4th through 7th covers. First through 3rd covers, 2 lbs. 50% DDT (1 lb. DDT). |
| 9. Not used in 1945. | 9. Di (methoxyphenyl) trichloroethane, 2 lbs. 50%, 1st through 7th covers. |
| 10. Not used in 1945. | 10. Hexachlorocyclohexane, 2 lbs., 50% (5% gamma isomer), 1st through 7th covers. |

[1] *Superla* used in all oil emulsions.

moth activity in Doniphan County was light during the first brood of 1946 due to a light carry-over of overwintering larvae from a small 1945 apple crop and to increased spraying activity brought about by the use of DDT. Due to an early spring and excellent conditions for codling moth development, two full broods and a partial third brood of codling moth occurred in 1946.

MATERIALS AND DOSAGES.—The combinations of insecticides used in 1945 and 1946 are indicated in table 1.

RESULTS.—Data for the various insecticide tests for the control of codling moth in the Blair experiment orchard, Blair, Kansas, for 1945 and 1946 are recorded in table 2.

DISCUSSION.—The foliage on the trees sprayed with lead arsenate without a safener showed marked arsenical injury in 1945 and 1946. Trees sprayed with *Black Leaf 155Y* and oil during the one season had many yellow leaves by July 30 in 1946. This condition continued throughout the remainder of the season resulting in a severe loss of leaves and a heavy pre-harvest apple drop. No leaf injury occurred where other *Black Leaf 155* combinations were used.

Trees of the 40 per cent DDT plot showed a distinct copper color of foliage by September 1, 1945, due to a heavy outbreak of mites. The trees sprayed with this DDT were the only trees in the plots under test that showed damage by the mites in 1945.

An examination of leaves on trees in

**Table 2.—Percentages of wormy and stung apples during various periods and the entire seasons.**

| Treatment Number and Year | Apples Dropped to Preharvest | | | Preharvest Drops | | | Harvest Counts | | Summary (Entire Season) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total per Plot | Per Cent Wormy | Per Cent Stung | Total per Plot | Per Cent Wormy | Per Cent Stung | Per Cent Wormy | Per Cent Stung | Total per Plot | Per Cent Wormy | Per Cent Stung | Per Cent Clean |
| 1. 1945 | 395 | 6.3 | 4.8 | 800 | 10.5 | 18.8 | 6.2 | 7.4 | 2195 | 7.8 | 11.1 | 81.1 |
| 1946 | 255 | 0.8 | 0.1 | 384 | 2.1 | 3.1 | 0.9 | 3.6 | 1639 | 1.2 | 3.4 | 95.4 |
| 2. 1945 | 195 | 3.6 | 1.0 | 558 | 10.0 | 12.4 | 3.0 | 2.9 | 1484 | 5.7 | 6.2 | 88.1 |
| 1946 | 243 | 5.8 | 1.6 | 249 | 0.8 | 3.2 | 1.5 | 2.1 | 1492 | 2.1 | 2.2 | 95.7 |
| 3. 1945 | 249 | 8.8 | 3.2 | 560 | 10.4 | 7.1 | 5.2 | 3.1 | 1809 | 7.3 | 4.4 | 88.3 |
| 1946 | — | — | — | — | — | — | — | — | — | — | — | — |
| 4. 1945 | 256 | 2.7 | 0.8 | 670 | 9.0 | 1.5 | 4.0 | 0.8 | 1721 | 5.8 | 1.0 | 93.2 |
| 1946 | 116 | 6.0 | 1.7 | 174 | 3.4 | 1.2 | 3.7 | 2.8 | 1290 | 3.9 | 2.5 | 93.6 |
| 5. 1945 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1946 | 217 | 5.1 | 0.4 | 409 | 2.2 | 0.5 | 1.3 | 0.4 | 1626 | 2.0 | 0.4 | 97.6 |
| 6. 1945 | 196 | 3.1 | 0.0 | 800 | 4.6 | 0.8 | 1.5 | 0.6 | 1996 | 2.9 | 0.6 | 96.5 |
| 1946 | 208 | 1.0 | 0.0 | 664 | 0.6 | 0.9 | 1.1 | 0.6 | 1872 | 0.9 | 0.6 | 98.5 |
| 7. 1945 | 299 | 20.1 | 0.7 | 776 | 19.5 | 3.5 | 4.6 | 2.0 | 2075 | 12.4 | 2.4 | 85.2 |
| 1946 | 117 | 0.0 | 0.9 | 303 | 2.0 | 0.7 | 1.2 | 0.4 | 1420 | 1.3 | 0.5 | 98.2 |
| 8. 1945 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1946 | 137 | 3.7 | 0.7 | 301 | 10.0 | 1.0 | 3.0 | 1.6 | 1438 | 4.5 | 1.4 | 94.1 |
| 9. 1945 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1946 | 264 | 3.8 | 0.4 | 376 | 4.3 | 2.1 | 1.7 | 1.2 | 1640 | 2.6 | 1.3 | 96.1 |
| 10. 1945 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1946 | 365 | 52.6 | 0.8 | 332 | 71.7 | 1.8 | 48.2 | 3.2 | 1697 | 53.7 | 2.4 | 43.9 |

the entire orchard, on July 2, 1946, showed few mites present except on trees sprayed with DDT in 1945. The leaves had over 200 mites per leaf and were beginning to turn a light bronze color. Leaves on trees in the remainder of the orchard surrounding the plots and sprayed with DDT-lead arsenate in 1946 were beginning to turn a light bronze color by July 24. No mites were found on leaves of trees in plots sprayed with DDT, *Black Leaf 155X* plus summer oil emulsion or *Black Leaf 155Y* plus summer oil emulsion. Although some mites could be found in the remainder of the spray plots, the population was not large enough to cause noticeable injury to the leaves on the trees. Mites caused the loss of some leaves in the lead arsenate plot by August 22. No mite damage was found in the other spray plots although on August 22 mites were found clustered in the calyx ends of apples in some of the plots.

On July 19, one half of a tree not included in the test plots and showing severe mite injury was sprayed with a special DDT mixture prepared for mite control. The other half of the tree was not sprayed with a mite-killing agent. At the time the tree was sprayed with the special DDT, as many as 160 mites and 120 mite eggs could be counted on each leaf. On July 24, the mites on the half of the tree sprayed with the mite-killing agent had been reduced to from 5 to none per leaf. Mites on the portion of the tree left unsprayed had increased to more than 200 per leaf. Most of the leaves had dropped from the unsprayed portion of the tree by August 22. Although some build-up of mites occurred on the leaves of the sprayed portion of the tree, the population was never great enough to cause increased injury to the leaves. The leaves on this portion of the tree remained green until killed by frost.

The high codling moth control obtained in the plots in 1946 is attributed to proper timing of sprays and spraying the remainder of the orchard surrounding the plots with DDT-lead arsenate combination.

Table 3.—Residue analyses. Grains per pound of fruit.

| Treatment Number and Year | Residue[1] (Grains $As_2O_3$ per Lb.) | | Residue[1] (Grains DDT or Methoxy per Lb.) | |
|---|---|---|---|---|
| | Unwashed | Washed | Unwashed | Washed |
| 1. 1945 | 0.047 | 0.011 | — | — |
| 1946 | 0.194 | 0.021 | — | — |
| 2. 1945 | 0.160 | 0.018 | — | — |
| 1946 | 0.294 | 0.029 | — | — |
| 3. 1945 | 0.027 | 0.009 | — | — |
| 1946 | — | — | — | — |
| 4. 1945 | 0.027 | 0.005 | — | — |
| 1946 | — | — | — | — |
| 5. 1945 | — | — | — | — |
| 1946 | — | — | 0.048 | 0.030 |
| 6. 1945 | 0.007 | 0.002 | 0.026 | — |
| 1946 | — | — | 0.021 | 0.027 |
| 7. 1945 | 0.016 | 0.002 | 0.051 | — |
| 1946 | — | — | 0.058 | 0.046 |
| 8. 1945 | — | — | — | — |
| 1946 | — | — | 0.027 | 0.028 |
| 9. 1945 | — | — | — | — |
| 1946 | — | — | 0.038 | 0.027 |
| 10. 1945 | — | — | — | — |
| 1946 | — | — | — | — |

[1] Residue analyses were made by Dr. A. T. Perkins, Kansas Agr. Exp. Sta.

No undesirable flavor was detected at harvest time in apples from plots sprayed in 1946 with hexachlorocyclohexane.

SUMMARY.—All spray combinations tested in 1946 except hexachlorocyclohexane gave excellent control of codling moth. The variation in percentage of control obtained was a 4.9 per cent spread between the most effective and the least effective of the better spray combinations tested during the season.

Hexachlorocyclohexane was the least effective of all spray combinations tested in 1946. Only 43.9 per cent clean fruit resulted from the use of this material.

Trees in plots sprayed with *Black Leaf 155*—DDT combinations gave excellent codling moth control in 1945 and 1946. The percentage of control ranged from 96.5 per cent clean fruit in 1945 to 98.5 per cent clean fruit in 1946.

The use of 50 per cent DDT in 1946 resulted in 98.2 per cent clean fruit. In 1945, 40 per cent DDT was not used in sufficient dosage and gave only 85.2 per cent clean fruit.

Lead arsenate alone and lead arsenate-zinc sulfate-summer oil emulsion were about equally effective in controlling codling moth in 1945 and in 1946. The lead arsenate when used alone had the highest number of stings of any spray or spray combination tested.

The trees in the plots sprayed with di (methoxyphenyl) trichloroethane in 1946 gave 96.1 per cent clean fruit.

The trees in the plot sprayed with the special mite-killing mixture of DDT in 1946 gave 94.1 per cent clean fruit.

*Black Leaf 155* plus summer oil emulsion gave equally effective control of codling moth in 1945 and 1946. In 1945, 93.2 per cent of the fruit was clean and in 1946, 93.6 per cent.

The DDT mixture prepared for mite control proved to be effective for the mites. Mites did not build up enough to injure foliage in any of the plots except the 40 per cent DDT in 1945 and lead arsenate when used alone in 1946. No mite build-up occurred in 1946 in plots sprayed with 50 per cent DDT.

The unwashed samples of harvest apples which had been sprayed with 40 per cent DDT in 1945 and 50 per cent DDT in 1946, when analyzed for this chemical, had a residue over the unofficial residue tolerance of 0.049 grain of DDT per pound of fruit. Samples of washed and unwashed apples which had been sprayed with *Black Leaf 155*—DDT-summer oil emulsion, di (methoxyphenyl) trichloroethane or mite-killing DDT were below the unofficial residue tolerance for DDT.

Residue analyses indicate the acid wash used to remove arsenical residue from fruit removes little if any DDT or di (methoxyphenyl) trichloroethane residue. Most of the latter and DDT residue is removed through handling and weathering.

Washed samples from plots sprayed in 1946 with lead arsenate-zinc—sulfate-summer oil emulsion, when analyzed for arsenic, had a residue of 0.029 grain per pound of fruit. The apple samples from all other plots after acid washing were below the arsenic tolerance of 0.025 grain per pound.—2-6-47.

# The Mexican Bean Beetle in California

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Late in July 1946, the Mexican bean beetle, *Epilachna varivestis* Muls., was found infesting lima beans at Montalvo in Ventura County. This represented not only the first established infestation in California but also the first infestation on the Pacific Coast. Though the species has been known to entomologists for over 75 years and is indigenous to Mexico and the Southwest, east of the desert area, and has spread throughout the eastern United States, even up into Canada, no spread to the westward has previously been recorded.

Immediate and intensive survey showed approximately 2000 acres of nearly contiguous plantings to be infested, in part or in whole, lying in the center of 40,000 acres of the most productive bean land in the state. Some of this land has been continuously planted to beans for over 50 years. As beans, both fresh and dry, represent one of the major agricultural crops of the state, having a value in excess of $60,000,000 annually, there was no question in the minds of either state or county agricultural officials but that immediate suppressive measures should be attempted. In this thought they were fully supported by the growers.

Early survey results indicated that the infestation centered in a 25 acre field which showed considerable plant injury and a relatively heavy population of adult beetles. Through funds made immediately available by the local bean-grower associations and by the county board of supervisors, this planting was purchased by the County Agricultural Commissioner and the plants first oil-sprayed to knock down the beetles, then burned with a tractor-drawn power burner, and the area repeatedly disked to a depth of several inches. Undoubtedly this prompt action prevented a widespread dispersal of adult beetles to adjoining or even more distant properties.

The completed survey showed other infestations to be limited to a 6-mile radius from this field with the spread more evident to the north and east in the direction of the prevailing wind. The degree of infestation decreased rapidly in direct ratio to the distance from this center. In the more distant fields infestations were restricted to a single spot of less than a dozen plants or occasionally even a single plant, indicating very recent establishment.

Just how this infestation originated, or when, will probably never be known. While host carriers from other infested states have always been kept under close surveillance, particularly fresh *green* beans, it was felt that there were so many possible avenues of entry that would *not* be subject to control that quarantine action would not justify the penalties that would be imposed. For that reason no quarantine had ever been established.

The beetle population at the time the infestation was found and the pattern of recorded spread indicated that its presence was of more than 1 year's standing but hardly of more than 3 or 4. Investigation of the ground litter under a eucalyptus windbreak along the western edge of the original field uncovered dead adults which had failed to survive winter hibernation in sufficient numbers to indicate the presence of an appreciable population during the preceding year. It is significant that along the southern edge of this same field there was a spur track serving a citrus packing house on which reefer cars, which had previously been used in the transportation of perishables on the eastern seaboard, often stood for several days in some numbers with their doors open awaiting use in transporting citrus fruits to the East. These cars represent a very probable source of introduction as was established by federal survey with respect to initial infestations of Oriental fruit moth in the western states. There is, of course, the possibility that the beetle may have come in with the personal effects of Mexican Nationals who have been employed during peak harvest periods in considerable numbers throughout the state including Ventura County for the past several years.

The method of approach to be followed in attempting eradication of this advanced incipient infestation was given careful consideration by federal, state and county

Pacific Slope Branch Program.

agricultural authorities. A request to the federal Bureau of Entomology and Plant Quarantine brought Dr. Neale F. Howard to the Pacific Coast from the Columbus, Ohio, laboratory, and his long experience in the control of this insect in the east was made available to the group.

The possibility of establishing a host-free area to include all the land lying within the mountain-surrounded basin in which the infestation lay, to be continued for two or more years, was given serious consideration. Aside from the fact that if such action were taken it would have involved in excess of 40,000 acres usually planted to beans and would have represented an annual loss to the growers of more than $4,000,000 during the period it was maintained, there were two factors that definitely mitigated against such action. First, it was not known what native plants present in the area, not found in other infested areas, might be acceptable to the beetle, the presence of which would nullify such a program. Secondly, the beetle is such a strong flyer and can survive such appreciable periods without food, it was reasonably feared that the absence of host beans would force widespread dispersal with many beetles finding their way through the mountain passes or along the coast to equally heavily bean-planted areas in adjacent counties to the north and south. Also a heavily traveled four-lane arterial highway traversing the more heavily infested fields, offered an excellent opportunity for "hitchhiking" beetles to be carried into those same areas, suggesting the possibility of an infestation more widespread than so far recorded. For these reasons this approach was abandoned.

It was decided that the only practical approach was to keep all infested and contiguous or intervening fields within the area, together with a reasonable buffer acreage, continuously dusted throughout the balance of the growing season with the most effective poison available. Unfortunately this insect had been of such long standing in the east that all investigations had been conducted with the idea of developing those materials which would give the most effective control with no thought of eradication. The use of rotenone .5 per cent or .75 per cent, with a maximum recorded efficiency of 95 per cent under the most optimum conditions, was the only available recommendation of the authorities. Inasmuch as the biotic potential of this insect is such that survival is permitted at 99.6 per cent mortality, this material did not offer too much promise. In addition rotenone loses its toxicity rapidly under direct sunlight which under California conditions meant practically no residual value.

However, following the recommendation of the federal Bureau, the first dusting of the 2000 acres involved was accomplished using 0.75 per cent rotenone applied at the rate of 50 pounds per acre. Due to the advanced maturity of the vines at the time the initial infestations were first found, with the runners meeting in the rows, much of the application was necessarily by plane. Coverage of the underside of the foliage, however, was not as complete as desired. Where power ground machines were used, the results were little better. To assure effective coverage approximately 300 acres of the more heavily infested fields were actually dusted by hand using rotary hand dusters operated by a large crew of Mexican Nationals available during the slack citrus packing period.

As rotenone supplies were particularly tight at the time and the delivered price considerably above that of cryolite-50 (45 per cent sodium fluoaluminate), the second dusting, following the first by 2 weeks, was accomplished using the latter material, applied at the same rate per acre as the rotenone. Cryolite was not only more readily available and less costly but was near-equal to rotenone in efficiency and offered a greater residual action. The results obtained seemed comparable with those obtained with rotenone but neither was as effective as required.

During field screening tests by Mr. John Steinweden, departmental entomologist in supervisory charge of operations, which tests included many other available promising materials, he found that the addition of 2–3 per cent *Lethane 60* or *A-70* (two aliphatic thiocyanates) to the .75 per cent rotenone gave higher mortality of all stages of the beetle than did rotenone alone, though this action was not confirmed by tests made in the laboratory at Columbus by Dr. Howard using the same California prepared material.

However, the third and final dusting, which followed the second dusting by 2 weeks, was completed with this material. Harvesting operations precluded any further treatments during the 1946 season.

While it was true that adult beetles could be observed in infested fields throughout the period of these dusting operations there appeared to be little noticeable reproduction after the first applications. It was later evident that winter was entered with a greatly reduced population of beetles with the possibility of even these being weakened by the treatments.

It is interesting to record that as compared with figures quoted by investigators as late as 1926 covering control costs, the most common type of labor has jumped from 25 cents per hour then, to $1.00 an hour now with materials showing a comparable increase in cost. The total cost of each application in these operations averaged $9.00 per acre when using 50 pounds of dust per acre. If this insect were to be accepted as an established pest and control followed the three to five applications of dust as now recommended in the eastern states, the cost would be $36 to $45 per acre per year which is nearly prohibitive even in the exceptionally productive areas in California.

With completion of the 1946 control measures, thought was given to the program to be continued through the winter and the following season which would further the complete suppression sought, before such action was made impractical by widespread dispersal. The following program was worked out and put into practice:

1. Determination of the conditions or cover acceptable to the beetles for winter hibernation under California conditions.
2. Physical elimination of all such cover in so far as possible.
3. Maintenance of beetles, under controlled hibernation conditions and adequate safeguards, as an index to the time of spring emergence and percentage of winter survivals under California conditions.
4. Testing of any native plants not common to other infested areas suspected as being acceptable to the beetle as supplemental hosts.
5. Planting of trap crops, tentatively March 1st, along the margins of infested fields of record, in advance of commercial spring planting, normally occurring around May 1st, to trap early emerging beetles and discourage dispersal.
6. Intensive survey to determine any spread to points outside of the recorded infested area.
7. Dusting of all infested acreage of record including intervening acreage, and any found during current survey together with a buffer area when deemed desirable, using 1 per cent rotenone at the rate of 50 pounds per acre, applied every 2 weeks beginning with the formation of runners, with a minimum of three and a maximum of five applications. Reservation made to switch to any more effective material later found available.
8. Continuation of safeguard measures, restricting movement from infested fields, or from the quarantined area, of host carriers such as fresh and dry beans, bean straw and equipment used in the culture or harvesting of beans, to prevent further spread by controllable means.

During the winter it was found that the loose ground litter under eucalyptus windbreaks common to the area or under walnut or lemon trees in orchards adjacent to infested fields, was acceptable to the beetles as winter hibernation quarters. Ground litter under cypress windbreaks also common to the area was, however, found to be unacceptable. It seemed to allow the soil to dry out, a condition which apparently discouraged its use by the beetles. The beetles seemed to prefer to hide *under* rather than *in* the litter, in close contact with moist earth. Due to the readily available situations of this kind around or adjacent to nearly all bean plantings, there was apparently no inclination on the part of the beetles to leave the area, that is, so far as could be determined.

Beginning February 1st the ground litter was raked from under all such acceptable windbreaks and burned and the exposed ground sprayed with pyrethrum 1 to 400 to kill any escaped beetles, which material Steinweden had found by labora-

tory test to be toxic to the adult beetles. Roughly 5 miles of such windbreaks were cleaned up in this manner. At the same time, through grower cooperation, approximately 800 acres of walnut and lemon orchards adjacent to infested fields of record were double disked and any remaining ground litter close to the trees cleared in the same manner as under windbreaks. All weeds between infested fields and paralleling highways were oil sprayed.

Due to unseasonable dry conditions, it was not possible to plant the trap crops as planned on March 1st, and it was late in April before this was completed. Resultant plant growth paralleled that in some of the earlier commercial plantings which started under irrigation about the same time.

By June 1st it was determined that 37 per cent of the beetles placed in the controlled hibernation cage had emerged and 15 scattered adults had been picked up in the field about equally divided between the trap crops and earlier commercial plantings. So far, the latter have been restricted to those fields which were most heavily infested last season. Three masses of eggs had also been found, together with a few plants showing fairly heavy adult feeding. No larvae have so far been observed this season. As these early incipient infestations were found, all insects and eggs which could be located by intensive visual inspection were hand collected and destroyed, the infested plants pulled and burned and all plants within a 50 foot radius hand dusted with 1 per cent rotenone.

Field dusting started at about this same time, using 1 per cent rotenone applied by power ground machines. The first dusting of all infested fields of record was completed by June 15 and the second dusting well underway. By mid-June plant runners were beginning to meet in the centers of the rows. So far there has not been a sufficient field population of beetles in any stage to determine accurately the effectiveness of the increased strength rotenone as used this season. No more effective material, however, has yet been discovered.

Through the cooperation of the Division of Truck Crop and Garden Insect Control of the Federal Bureau of Entomology and Plant Quarantine, investigations were conducted during the winter and spring in the ecology of the insect under California conditions. and in a study of potential native host plants. These studies were conducted by J. C. Elmore of the federal Bureau who, fortunately, was very familiar with the area and the host crop, using federal laboratory facilities available in the area. The findings have been a definite aid in timing this season's operations and in eliminating the possibility of any new native hosts, so far, as being acceptable to the beetle, encouraging from the eradication standpoint. His observations in home gardens in which beans were present throughout the winter, failed to show any activity on the part of the beetle during that period.

With the finding of the first beetles in 1946, quarantine safeguards against controllable spread were imposed. An area encompassing all infested plantings with a generous buffer area was placed under quarantine. No potential carriers were permitted to move from an infested property excepting under supervised fumigation nor from the quarantined area to points outside excepting under similar restrictions. Investigation of harvesting operations showed that numerous live beetles survived the field process in the trash which was gathered and burned. Some live beetles were found in the harvested beans as sacked in the field and all such beans were required to be fumigated before moving to a warehouse. No beetles were found to survive the final recleaning process, and such beans were permitted to be moved without further treatment. Harvesters and field wagons used in harvesting were fumigated before moving from an infested property. Green beans moving to quick freeze plants outside the area were fumigated in the field before movement. In all of these operations the growers were fully cooperative. Ventura County Agricultural Commissioner C. J. Barrett has been in field charge of operations and has taken an aggressively active part in seeing that all quarantine requirements were fully carried out.

Investigations by Steinweden showed that both fresh and dry beans were tolerant and all stages of the beetle completely susceptible to methyl bromide when exposed to 3 pounds for 2 hours under a gas-tight tent at 80° F. or 3.5 pounds at 70° F. or 4 pounds at 60° F. Where time was not important, 2 pounds for 12 hours

or 1 pound for 24 hours was found effective and approved for dry beans or bean straw. In the case of harvesting equipment the use of cyanide under ordinary canvas was found effective and approved when used at the rate of 1.5 ounces of sodium cyanide or its equivalent for 1 hour at temperatures above 50° F. In such cases liquid HCN was used

In addition fo $3000 appropriated by the Independent Bean Growers Association, $5000 by the Ventura County Bean Growers Association and $5000 by the Ventura County Board of Supervisors, $102,000 has been budgeted by the state Department of Agriculture to cover operations up to June 30, 1947, with approximately $120,000 budgeted for each of the next two succeeding years.

Whether eradication of this infestation can be accomplished only time can tell. Most eastern entomologists familiar with this insect were rather cold to such a suggestion when their advice was solicited. However, not being inhibited by experience, the value of the crop, the recognized seriousness of the insect as a pest of beans, and the potential high cost of control over an extensive acreage if accepted as an established pest, have left no other course open but to try.—7-27-47.

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# Influence of Various Exposure-Concentration Combinations on Mortality of the California Red Scale in HCN Fumigation

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The influence of the length of the exposure period to hydrocyanic acid on the kill of California red scales, *Aonidiella aurantii* (Mask.), is of practical importance in field fumigations. In field fumigation each tree is usually given an exposure of 45 to 50 minutes. Woglum (1923) states that, with untreated cloth covers on the trees, an exposure of 45 minutes gives nearly as good results as one of an hour because most of the gas escapes before the expiration of an hour. With covers that are more nearly gas tight appreciable concentrations exist at the end of 45 minutes, as shown by Lindgren & Dickson (1943) and Fulton & Nelson (1946).

If the present untreated, porous-cloth coverings are replaced by more nearly gas tight coverings, different results may be expected. Laboratory and field studies were therefore made of the influence of the duration of the exposure, in combination with other factors, on the kill of scales in fumigations with hydrocyanic acid. The treatments included exposures to both constant and decreasing concentrations without and with preliminary exposure to low concentrations of gas to produce stupefaction of the scales.

EXPERIMENTAL PROCEDURE.—Resistant scale insects reared on lemon fruits were fumigated in the laboratory under controlled conditions. Unless otherwise stated, the insects were obtained in the field and each mortality figure was based on 1200 scales. Fifty live insects in the same developmental stage were marked on each fruit prior to treatment. Those reared in the laboratory were subjected to fluctuating temperatures during development, with two exceptions. The scales were preconditioned and postconditioned for 4 hours at 59° F. and fumigated at the same temperature. After the postconditioning period the scales were held at daily fluctuating temperatures until the mortalities were determined.

In the laboratory the fumigations were made in a chamber designed by Howard (Yust & Howard 1943) and modified by Fulton (Fulton & Busbey 1943). The insects were subjected to constant or decreasing concentrations for 15 to 90 minutes in fumigations in which the products of the average concentration and exposure time were equal. This was accomplished by treatment with a high concentration for a short time and decreasing the concentration for successive increases in the exposure interval. In tests in which

constant and decreasing concentrations were compared, the average of the decreasing concentrations was equal to the constant concentrations.

In the field experiments scales reared in the laboratory or collected in the field were fumigated in citrus trees covered with tents in a manner similar to regular field fumigations. The scale-infested fruits were placed in wire-screen baskets and hung near the center of the tree. Groups of the insects were removed at intervals after introduction of the gas, to determine the kill obtained for the respective periods of exposure to hydrocyanic acid.

LABORATORY TESTS. *Constant concentrations.* Scales in the second molt which had been reared in the laboratory at a constant temperature of 77° F. were fumigated in the laboratory with constant concentrations of hydrocyanic acid. The scales were exposed for different periods at such concentrations that the time-concentration product was 48 at each exposure. The treatment was repeated on 2 days and each mortality figure was based on 600 insects. The concentrations were 0.8, 1.2, 1.6, and 2.0 mg. per liter, and the respective exposures were for 60, 40, 30, and 24 minutes. The corresponding mortalities were $65.7 \pm 4.0$, $75.3 \pm 3.4$, $79.3 \pm 2.5$, and $84.3 \pm 2.0$ per cent. The kills were proportional to the concentration, although the concentration-time products were the same.

Tests were subsequently made to determine whether or not the same reaction occurred when the scales were prefumigated with sublethal dosages. Scales in the second molt were prefumigated with a concentration of 0.1 mg. per liter for 10 minutes, and four different lots were given final fumigations such that the time-concentration products were the same. Each exposure included 600 insects. The concentrations were 0.7, 1.4, 2.1, and 4.2 mg. per liter for 90, 45, 30, and 15 minutes, respectively. The corresponding mortalities were $91.7 \pm 1.6$, $88.0 \pm 1.6$, $92.8 \pm 1.6$, and $93.7 \pm 1.4$ per cent. The kill for the lowest concentration was not significantly lower than that for the highest. Prefumigation appeared to have eliminated the possibility of correlation between concentration and kill.

Mature female scales were fumigated, without and with prefumigation, in order that the reaction of this developmental stage might be observed. The prefumigation was for 10 minutes with a concentration of 0.1 mg. per liter. The final exposures and the corresponding concentrations, as well as the results, are given in table 1. The product of concentration and time was approximately the same in each group of four exposures. Without prefumigation the kill was again proportional to the concentration. With prefumigation the kills for the three highest exposures were not significantly different from each other, but were significantly higher than that for the 15-minute exposure.

**Table 1.—Mortality of mature female scales with constant concentrations of hydrocyanic acid for different exposure periods giving the same concentration-time product.**

| Exposure Time, Minutes | Concentration, Milligrams per Liter | | Mortality, Per Cent | |
|---|---|---|---|---|
| | No Prefumigation | Prefumigation | No Prefumigation | Prefumigation |
| 90 | 0.20 | 0.70 | 60.4 | 94.2 |
| 45 | 0.39 | 1.39 | 69.7 | 93.0 |
| 30 | 0.59 | 2.10 | 75.2 | 93.1 |
| 15 | 1.20 | 4.21 | 89.5 | 88.6 |

LABORATORY TESTS. *Decreasing concentrations.* Scales in the second molt reared in the laboratory were fumigated with decreasing concentrations, without and with prefumigation. The prefumigation was with a concentration of 0.05 mg. per liter for 20 minutes. The tests were repeated on 2 days. The exposures and kills are given in table 2.

Without prefumigation the kills were approximately the same for the three longest exposures and with prefumigation were approximately the same for the three shortest exposures. The percentages of kill for the 15- and 90-minute exposures were significantly different without and with prefumigation but were in reverse order. Without prefumigation the mortality for the 15- and 90-minute exposures increased with increasing concentration, but with prefumigation the reverse was true. A direct correlation between the initial concentration and the kill was previously shown by Yust *et al.* (1943) in tests with decreasing, constant, and increasing concentrations.

LABORATORY TESTS. *Constant vs. de-*

**Table 2.—Mortality of mature female scales with decreasing concentrations of hydrocyanic acid for different exposure periods giving the same concentration-time product.**

| Exposure Time, Minutes | Concentration, Milligrams per Liter | | | | Mortality, Per Cent | |
|---|---|---|---|---|---|---|
| | No Prefumigation | | Prefumigation | | No Prefumigation | Prefumigation |
| | Range | Average | Range | Average | | |
| 90 | 2.05–0.04 | 0.40 | 3.67–0.04 | 0.71 | 91.4 | 78.3 |
| 45 | 2.20–0.15 | 0.80 | 3.95–0.26 | 1.38 | 91.4 | 74.2 |
| 30 | 2.50–0.45 | 1.21 | 4.37–0.74 | 2.11 | 92.9 | 74.8 |
| 15 | 3.44–1.54 | 2.41 | 6.03–2.70 | 4.18 | 96.2 | 73.2 |

*creasing concentration.* Mature females and scales in the second molt were exposed for 15 and 90 minutes to constant and decreasing concentrations in fumigations without and with prefumigation. The kills with both constant and decreasing concentrations for 15 and 90 minutes may be compared for the same stage and pretreatment. The concentrations and kills in the tests are shown in table 3. Each mortality figure is based on tests repeated on at least 2 days and on 1200 insects, except for kills of prefumigated scales in the second molt, which were based on 2400 insects.

**Table 3.—Influence of constant and decreasing concentrations of hydrocyanic acid for two exposure periods giving the same concentration-time product on the mortality of second-molt and mature-female scales, without and with prefumigation.**

| Exposure Time, Minutes | Concentration, Milligrams per Liter | | | Mortality, Per Cent | |
|---|---|---|---|---|---|
| | Constant | Decreasing | | Constant Concentration | Decreasing Concentration |
| | | Range | Average | | |
| **Scales in Second Molt** | | | | | |
| No Prefumigation | | | | | |
| 90 | 0.4 | 2.05–0.04 | 0.4 | 59.6 | 91.4 |
| 15 | 2.4 | 3.44–1.54 | 2.4 | 94.3 | 96.2 |
| Prefumigation | | | | | |
| 90 | 0.7 | 3.61–0.06 | 0.7 | 73.2 | 83.3 |
| 15 | 4.2 | 5.97–2.72 | 4.2 | 79.7 | 78.0 |
| **Mature Females** | | | | | |
| No Prefumigation | | | | | |
| 90 | 0.2 | 1.00–0.02 | 0.2 | 70.6 | 95.6 |
| 15 | 1.2 | 1.71–0.78 | 1.2 | 95.7 | 97.2 |
| Prefumigation | | | | | |
| 90 | 0.7 | 3.63–0.06 | 0.7 | 94.2 | 95.8 |
| 15 | 4.2 | 5.95–2.68 | 4.2 | 88.6 | 85.8 |

The data further verify the indications in the previous tests. In the tests with both stages without prefumigation the kills were lower with lower concentrations, although in the tests with mature females treated with decreasing concentrations the kills were not significantly different. With prefumigation and decreasing concentrations the kills were significantly higher for the longer exposures in both stages. With prefumigation and constant concentrations the length of the exposure had a significantly greater effect on the kill of mature females than the amount of the concentration, while the reverse was true against the scales in the second molt. In the tests with constant concentrations without prefumigation it appears likely that some protective stupefaction occurred during the first few minutes of the exposure to the lower concentration. With decreasing concentrations there was less protective stupefaction, apparently owing to higher initial concentrations. Similar indications were also obtained in other experiments, not reported here, both without and with prefumigation.

It should be noted that in the 15-minute exposures the kills with constant and decreasing concentrations were nearly equal in each case. In the 90-minute exposures the kills for the decreasing concentrations were significantly higher except for the prefumigated mature-female scales. The data suggest that no stupefaction occurred during the final fumigation in the 15-minute exposures or in the 90-minute exposure of mature females that had been prefumigated. Stupefaction might be expected in the two 90-minute exposures without prefumigation because of the relatively low constant concentrations used. A lower kill of scales in the second molt which were prefumigated and then fumigated with a constant concentration might also be expected, because it was shown by Yust *et al.* (1944) that scales in this stage require higher concentrations for stupefaction than do mature-female scales. The data suggest no explanation for higher kills in the 90-minute exposures.

The results do not demonstrate a clear-

cut advantage for exposures of either 15 or 90 minutes. In the tests without prefumigation, especially with constant concentrations, the kills in the 90-minute exposures were lower than in those for 15 minutes, but the lower kills were probably due to protective stupefaction in the course of the fumigation. In field fumigations with relatively gastight tents the initial concentrations are in excess of 1 mg. per liter; so protective stupefaction from this dosage should be minimal. In the tests with prefumigation the kills were generally higher in the 90-minute exposures. In the field some protective stupefaction from drift gas may be expected, which will provide a comparable situation. The advantage of increased kills obtained in 90-minute exposures is offset by the increased time required to fumigate a grove. Other factors may also be introduced.

TIME-MORTALITY TEST IN THE LABORATORY.—To determine whether increasing the exposure time overcomes stupefaction under certain conditions, mature female scales were fumigated, without and with prefumigation, with constant concentrations for 15, 30, 45, 65, and 90 minutes. Without prefumigation the concentration was 0.5 mg. per liter and with prefumigation it was 1.4 mg. The prefumigation was for 10 minutes with a concentration of 0.1 mg. per liter. Each mortality figure was based on 600 insects. In figure 1 the mortality in probits is plotted against the time in logarithms, according to the Bliss method. The regression equation for the data obtained in the tests with prefumigation prior to final fumigation was $Y=5.74+3.39(X-1.409)$, and for the data obtained without prefumigation was $Y=5.55+3.39\ (X-1.462)$. Since the mortality curves are approximately parallel, the data indicate that increasing the exposure does not overcome protective stupefaction under these conditions.

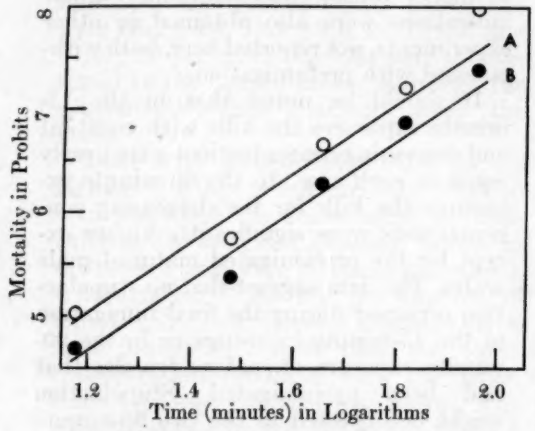


FIG. 1.—Mortality of mature females of the California red scale fumigated for different exposure times, with prefumigation (A) and without prefumigation (B).

FIELD FUMIGATIONS WITH VARYING EXPOSURE PERIODS.—Mature female scales were fumigated for 5, 10, 25, and 45 minutes under a citrus tree covered with a tent to determine the kill resulting from decreasing concentrations in the field. The test was accomplished by removing scale-infested fruits from under the tent at these intervals after hydrocyanic acid was introduced. The tent covering for the tree was of 8-ounce army duck. A 20-cc. schedule was used, and the temperature at the beginning of the fumigation was 55° F. At each interval three groups of 1200 scales each were removed—namely, (1) a group not prefumigated, (2) a group prefumigated for 45 minutes, and (3) a group prefumigated for 25 minutes. The prefumigations were made in the laboratory fumigation chamber for 45 minutes with a concentration ranging from 0.13 to 0.02 mg. per liter and for 25 minutes with a concentration ranging from 0.04 to 0.02 mg. per liter. The latter was simultaneous with the last 25 minutes of the 45-minute prefumigation exposure. There was a 5-minute interval between the end of the prefumigation and the beginning of the final fumigation. The results are presented in table 4.

The kills in the 45-minute exposures were not significantly higher than those in the 25-minute exposures. Similar results were indicated in tests of scales in the second molt. The results suggest that the low concentrations near the end of the exposure have little effect on the mortality in the field. The dosage for 25 minutes was 86.6 per cent of that for 45 minutes as judged by the time-concentration product. In similar tests without prefumigation Lindgren (1941) obtained the same results. Kirkpatrick (1939) also reached the same conclusion, but Swain (1918) considered that 30 minutes was not sufficient to obtain the highest kills.

A similar field test was made with scales

**Table 4.—Influence of various exposures to hydrocyanic acid on the mortality of mature female scales in the field, without and with prefumigation for different periods.**

| Exposure Time, Minutes | Average Concentration, Milligrams per Liter | Time-Concentration Product | Mortality, Per Cent | | |
|---|---|---|---|---|---|
| | | | No Prefumigation | 45-Minute Prefumigation | 25-Minute Prefumigation |
| 5 | 2.93 | 14.65 | 96.8±0.8 | 80.8±2.2 | 41.0±4.4 |
| 10 | 2.21 | 22.10 | 98.8±0.4 | 91.3±1.1 | 60.8±3.1 |
| 25 | 1.34 | 33.50 | 99.9±0.08 | 91.3±1.3 | 81.2±2.5 |
| 45 | 0.86 | 38.70 | 99.9±0.08 | 92.8±1.4 | 76.9±2.6 |

in the second molt in fumigations under 8-ounce army duck and plastic-coated tenting. The latter was semi-gastight and permitted less diffusion of hydrocyanic acid gas through the tent cover, as shown in table 5. The scales were not prefumigated on two nights and were prefumigated on two other nights. Each treatment was made on a different night; so only the kills for the various exposures in the same treatment are comparable. The prefumigation concentration ranged from 0.1 to 0.03 mg. per liter for 45 minutes. Without prefumigation the schedule under the duck tent was 20 cc. and under the plastic tent 14 cc., and with prefumigation it was 28 and 20 cc., respectively.

**Table 5.—Influence of 10-, 25-, and 45-minute exposures to hydrocyanic acid on the mortality of California red scales in the second molt, not prefumigated and prefumigated, in the field under army duck and plastic-coated tents.**

| Tent Material and Exposure Time, Minutes | Concentration, Milligrams per Liter | | Time-Concentration Product | Mortality, Per Cent |
|---|---|---|---|---|
| | Average | Final | | |
| | No Prefumigation | | | |
| Duck | | | | |
| 10 | 2.38 | 1.33 | 23.8 | 65.8 |
| 25 | 1.36 | 0.39 | 34.0 | 74.7 |
| 45 | 0.83 | 0.13 | 37.4 | 75.5 |
| Plastic-coated | | | | |
| 10 | 1.93 | 1.46 | 19.3 | 47.3 |
| 25 | 1.30 | 0.61 | 32.5 | 59.7 |
| 45 | 0.90 | 0.27 | 40.5 | 66.2 |
| | Prefumigation | | | |
| Duck | | | | |
| 10 | 3.41 | 2.14 | 34.1 | 58.3 |
| 25 | 2.07 | 0.63 | 51.8 | 71.9 |
| 45 | 1.26 | 0.19 | 56.7 | 73.8 |
| Plastic-coated | | | | |
| 10 | 2.71 | 2.10 | 27.1 | 27.2 |
| 25 | 1.92 | 0.92 | 46.1 | 45.2 |
| 45 | 1.27 | 0.35 | 57.2 | 55.2 |

The liquid hydrocyanic acid was introduced under the tents with a blower-type applicator (Fulton & Nelson 1946), which was left under the tent for 1 minute to circulate the gas.

With the duck tents the time-concentration products for the 25-minute exposures without and with prefumigation were 90.9 and 91.4 per cent of those for 45 minutes; and with the plastic coverings for 25 minutes they were 80.2 and 80.6 per cent, respectively. The less porous, plastic-treated tent retained enough more gas to the end of the 45-minute exposures to increase significantly the kill over that of 25-minute exposures. It appears that in the fumigation of many trees under the duck tents the concentration during the last 20 minutes was so low that it was ineffective. The concentrations were determined in the field fumigation of 211 trees over about a 3-year period. The time-concentration product for the first 25 minutes was above 86.5 per cent of that for the entire 45-minute exposure in about 33 per cent of the fumigations.

SUMMARY.—Resistant California red scales, *Aonidiella aurantii* (Mask), were fumigated in the laboratory and in the field with hydrocyanic acid to determine the influence of the length of the exposure period, in combination with other factors, on the mortality. Tests were made in the laboratory with different exposure periods and different concentrations whose products of concentration and time were the same. The treatments included exposures to both constant and decreasing concentrations, without and with prefumigation exposures that produced stupefaction.

Without prefumigation in tests with decreasing and constant concentrations the kills in general were directly proportional to the concentration when the products of concentration and time were

the same. In similar tests after prefumigation the direct correlation between concentration and kill disappeared. The results suggest that the stupefaction may occur during the fumigation with lower concentrations and longer exposures.

In three out of four cases with prefumigation somewhat better kills were obtained with 90-minute exposures than with 15-minute exposures, with equivalent time-concentration combinations. No adequate explanation is apparent.

In 15-minute exposures the kills for constant and decreasing concentrations were approximately equal in tests with mature females and scales in the second molt without and with prefumigation. In 90-minute exposures higher kills were obtained with decreasing than with constant concentrations in both stages without prefumigation, and with prefumigation higher kills were obtained with decreasing than with constant concentrations in the second molt but not with mature females. These data indicate that protective stupefaction resulted from the final constant concentrations in the 90-minute exposures except for the mature females with prefumigation.

In three field fumigations with regular duck tents the kills at the end of 25 minutes were approximately the same as at the end of 45 minutes. The dosage for 25 minutes was 86.6 per cent of the dosage for 45 minutes, as judged by the product of concentration and time. In the fumigation of 211 trees in the field the time-concentration product for 25 minutes was above 86.5 per cent of that for 45 minutes in one-third of the cases.

With plastic-coated coverings which were semi-gastight the kills for 45-minute exposures were significantly higher than at 25 minutes.—6-30-47.

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# Thermal Decomposition of DDT and Benzene Hexachloride Mixtures

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Some of the studies of the compatability of DDT with various materials (Fleck & Haller 1945, 1946) and of the thermal decomposition of DDT (Balaban & Sutcliffe 1945; Flenner 1946; Gunther & Tow 1946, 1947; Scholefield *et al.* 1946) indicate that a thermal type decomposition may be either induced or accelerated by the presence of traces of certain substances, including the so-called "halogen carriers" such as members of the iron group. Two anti-iron catalysts have been shown to

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inhibit effectively such catalyzed thermal (laboratory) decompositions (Gunther & Tow 1946, 1947). These evidences leave no doubt that the first step in the thermal decomposition of p, p'-DDT is dehydrohalogenation to the ethylene, 2,2-bis-(p-chlorophenyl)-1, 1, 1-trichloroethylene.

Previous studies have indicated that buffering this reaction inhibits the decomposition only slightly. Although other published data (Balaban & Sutcliffe 1945; Flenner 1946; Fleck & Haller 1945, 1946) indicate fairly conclusively that chloride ion is not a catalyst for the decomposition of DDT, and that catalysis by hydrogen chloride is doubtful as well (autocatalysis), recent developments have indicated the desirability of reinvestigating these possibilities.

For example, since some DDT is currently being used in admixture with other insecticidal materials, the possibility that addenda capable of liberating hydrogen chloride might catalyze the thermal decomposition of the DDT present became of interest. Such an addendum is benzene hexachloride (more precisely designated as 1, 2, 3, 4, 5, 6-hexachlorocyclohexane). Although this molecule is generally conceded to be thermally more stable than that of DDT, it nevertheless will eliminate three molecules of hydrogen chloride per molecule of parent compound, especially under the influence of mild alkali, to form essentially 1, 2, 4-trichlorobenzene (Slade 1945; Gunther & Blinn 1947).

As demonstrated in the present investigation, however, temperatures of 120° C. or lower induce negligible decomposition of the technical grade hexachloride, whereas at the same temperature and in the same apparatus it has been shown that a technical grade DDT decomposes completely (Gunther & Tow 1946, 1947) to liberate 1.14 moles of hydrogen chloride per mole of parent mixtures. Since technical grade benzene hexachloride is a complicated mixture containing predominantly four stereoisomers, namely, the so-called alpha, beta, gamma, and delta isomers, it seemed worthwhile to study the behavior of each isomer under conditions conducive to the decomposition of DDT, alone and in admixture with DDT. The melting ranges of the isomers used are shown in table 1; since this investigation was undertaken a fifth or "epsilon" isomer, m.p. 218.5–219.3° C., has been found (Kauer *et al.* 1946).

Admixture of DDT with technical benzene hexachloride, or with its pure isomers however, resulted in pronounced decomposition of the DDT under the conditions herein described. Furthermore, the decomposition of the DDT was shown definitely to be neither chloride catalyzed nor autocatalytic.

**Table 1.—Isomers of benzene hexachloride and their melting ranges.**

| Isomer | Melting Range, °C. | |
|---|---|---|
| | Experimental[1] | Literature[2] |
| Alpha | 153–154 | 157.5–158.0 |
| Beta | 298–300 | 309 |
| Gamma | 112.2–113.8 | 112.5 |
| Delta | 136–137 | 138–139 |

[1] Corrected.
[2] Slade (1945).

EXPERIMENTAL PROCEDURE.—Analyses of thermal stability were made in the same apparatus employed previously and in a similar manner (Gunther & Tow 1946, 1947). All reagents used in the titrations were restandardized every day, and only distilled water freshly redistilled from alkaline permanganate was used throughout. Into a 6-inch pyrex Schwartz U-shaped drying tube was placed 1–2 grams of the compound or comminuted mixture to be tested, and the tube was immersed to a depth of 3 inches in a butyl phthalate bath maintained at 110–120° C. A gentle current of dry, carbon-dioxide free air was drawn through the apparatus, then through a Fisher-Milligan gas washing bottle containing 300 milliliters of the especially distilled water. After heating 4–24 hours the contents of the absorption bottle were titrated with 0.1 N sodium hydroxide solution to the phenolphthalein end point. All mixtures were prepared on a weight-per cent basis.

Decomposition values are the averages of duplicate runs. These values, expressed as percentages, are based precisely upon the moles of chloride ion by titer per mole of DDT in the starting mixture. The validity of this assumption is demonstrated adequately by the results subsequently obtained.

STABILITY OF BENZENE HEXACHLORIDE.—As may be seen from the decomposition

**Table 2.—Thermal stability of benzene hexachloride and four of its isomers with and without added iron decomposition catalyst.**

| Material | Time 1 (Hour), | Per Cent Decomposition | Time 2 (Hours) | Per Cent Decomposition |
|---|---|---|---|---|
| Alpha Isomer | 4 | 0.00 | 24 | 0.07 |
| Beta Isomer | 4 | 0.00 | 24 | 0.00 |
| Gamma Isomer | 4 | 0.00 | 24 | 0.07 |
| Delta Isomer | 4 | 0.00 | 27 | 0.00 |
| Technical Grade | 6 | 0.13 | 24 | 0.25 |
| Alpha Isomer+$Fe^{+++}$[1] | 4 | 0.07 | 26 | 0.32 |
| Beta Isomer+$Fe^{+++}$ | 5 | 0.17 | 24 | 0.39 |
| Gamma Isomer+$Fe^{+++}$ | 4 | 0.12 | 24 | 0.36 |
| Delta Isomer+$Fe^{+++}$ | 4 | 0.00 | 24 | 0.15 |
| Technical grade+$Fe^{+++}$ | 5 | 0.55 | 24 | 0.76 |

[1] $Fe^{+++}$ added at 2–3 weight per cent in each case as $Fe(NO_3)_3 \cdot 9H_2O$.

data in table 2, the four pure isomers of benzene hexachloride were for all practical purposes equally stable to equivalent thermal treatment up to 120° C., whereas the technical grade material appeared to contain minute traces of a catalytic or other substance tending to accelerate the decomposition slightly.

In contrast to DDT (Gunther & Tow 1946, 1947) the effect of added iron up to 3 per cent may for all practical purposes be considered negligible even after 24 hours at 110–120° C. Nonetheless, from these data it is apparent that, under the conditions specified: (1) the beta and delta isomers were the most stable, (2) the alpha and gamma isomers possessed equivalent stabilities, (3) the delta isomer was the most resistant to the effects of added iron, and (4) added iron produced approximately a five-fold increase in the rates of thermal decomposition with all but the technical grade material where the increase was only three-fold, presumably attributable to traces of catalyzing substances already present.

STABILITY OF DDT AND BENZENE HEXACHLORIDE MIXTURES.—When equal quantities of DDT and the hexachloride were mixed intimately, with and without added iron, and heated as before, the results collated in table 3 were obtained.

It thus appears that mixtures of purified or technical DDT with the predominant isomers of benzene hexachloride or with the technical grade material were subject to considerable thermal decomposition under these conditions. With the exception of the alpha isomer, for whose behavior no explanation is offered, the addition of 2–3 per cent of ferric iron produced an average of 37.5 per cent increase in decomposition over a 24-hour period. Neglecting the value for the mixture containing the alpha isomer, the average per cent decomposition for those runs containing p, p′-DDT and catalyzed with iron was 127.8 per cent as contrasted with the 110.5 per cent decomposition for the p, p′-DDT-iron mixture. The corresponding values for the corresponding technical mixtures were 129.9 per cent and 114.5 per cent, respectively. Within experi-

**Table 3.—Thermal stability of DDT and benzene hexachloride mixtures (50 : 50) with and without added iron decomposition catalyst.**

| Material | Time 1 (Hour) | Per Cent Decomposition | Time 2 (Hours) | Per Cent Decomposition |
|---|---|---|---|---|
| Alpha Isomer+p,p′-DDT[1] | 4.5 | 64.3 | 24.5 | 82.8 |
| Beta Isomer+p,p′-DDT | 5.5 | 65.1 | 24.8 | 81.8 |
| Gamma Isomer+p,p′-DDT | 4.7 | 0.0 | 24.1 | 89.8 |
| Delta Isomer+p,p′-DDT | 4.5 | 62.0 | 24.5 | 88.1 |
| Technical grade+p,p′-DDT | 6.0 | 94.8 | 25.0 | 94.6 |
| p,p′-DDT | — | — | 93.0 | 0.0 |
| Technical DDT[2] | — | — | 96.0 | 0.4 |
| Technical grade+Technical DDT | 4.0 | 99.0 | 24.0 | 103.2 |
| Alpha Isomer+p,p′-DDT+$Fe^{+++}$[3] | 2.7 | 45.6 | 24.2 | 56.2 |
| Beta Isomer+p,p′-DDT+$Fe^{+++}$ | 4.0 | 110.8 | 24.0 | 116.4 |
| Gamma Isomer+p,p′-DDT+$Fe^{+++}$ | 5.5 | 125.6 | 24.1 | 132.2 |
| Delta Isomer+p,p′-DDT+$Fe^{+++}$ | 17.8 | 135.1 | 24.0 | 136.4 |
| Technical grade+p,p′-DDT+$Fe^{+++}$ | 4.7 | 120.5 | 24.7 | 126.2 |
| Technical grade+Technical DDT+$Fe^{+++}$ | 2.7 | 117.5 | 26.8 | 129.9 |
| p,p′-DDT+$Fe^{+++}$[4] | 4.0 | — | 24.0 | 110.5 |
| Technical grade DDT+$Fe^{+++}$[4] | 4.0 | 106.5 | 24.0 | 114.5 |

[1] Recrystallized repeatedly from ethanol, while avoiding contact with metal of any kind, to a constant melting point of 107.5 108.5° C. (cor.).
[2] Setting point 90.1° C. Iron-free sample, see Gunther & Tow (1947).
[3] $Fe^{+++}$ added at 2–3 weight per cent in each case as $Fe(NO_3)_3 \cdot 9H_2O$.
[4] Gunther & Tow (1947).

mental error, it appears that the benzene hexachloride enhanced by 16 per cent the effective iron catalyzed decomposition. Comparisons with the data from the iron uncatalyzed runs indicate possibly that secondary decompositions of the DDT were implemented to produce this effect.

STABILITY OF THE DDT TO CHLORIDE.—In order to evaluate the effects of hydrogen chloride and of chloride ion upon the stability of the DDT, 1-gram samples of the iron-free p, p′-DDT were introduced into 6-inch pyrex test-tubes that had been flushed thoroughly with dry nitrogen. Upon introduction of the addendum under study, the tube was sealed and immersed in the oil bath maintained at 110° C. After 24–48 hours, the tubes were opened and the per cent p, p′-DDT remaining in the reaction product was estimated by means of a melting-point composition curve for the parent DDT and its ethylenic dehydrohalogenation product.[1,2] Representative results are shown in table 4.

[1] The residue in the tube was dissolved in ether, washed thoroughly with water, dried, and evaporated.

[2] Our curve resembled very closely that of Scholefield, Bowden, and Jones (1946) with our eutectic containing 42 per cent p,p′-DDT and melting at 66.0°C. The phase diagram of the English workers indicates 43 per cent DDT and a melting point of 64.2° C.; in their discussion, however, the English workers specify that the eutectic contains 57.4 per cent DDT (p. 356). We believe they inadvertently interchanged this value with that for their DDT-naphthalene phase diagram (figure 3).

**Table 4.—Thermal stability of DDT in presence of HCl and of $Cl^-$ in sealed tubes.**

| MATERIAL | TIME (HOURS) | PER CENT DECOMPOSITION |
|---|---|---|
| Dry Air | 24 | 0 |
| Aq. HCL (11%, 1 ml.) | 24 | 7 |
| Anh. Alc. HCL (11%, 1 ml.) | 24 | 0 |
| Anh. HCL gas | 24 or 48 | 0 |
| Chlorobenzene (1 g.) | 24 | 54 |
| $ZnCl_2$ in EtOAc (80 ml. sat.) | 2 | 0 |
| $ZnSO_4$ in EtOAc (80 ml. sat.) | 2 | 0 |

SUMMARY AND CONCLUSIONS.—Thus it becomes apparent that benzene hexachloride in any of the forms studied has a pronounced deleterious effect upon the thermal stability of DDT in admixture. In all probability the hexachloride preparations contained minute traces of iron or other catalyzing materials which elicited this response. Benzene hexachloride and its alpha, beta, gamma, and delta isomers appear to be quite stable thermally to 120° C. even with added ferric iron, in contradistinction to the behavior of DDT under similar experimental conditions.—8-18-47.

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# Toxicity to House Flies of the Pyrethrins and Cinerins, and Derivatives, in Relation to Chemical Structure

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The insecticidal constituents of pyrethrum flowers have recently (LaForge & Barthel 1944a) been shown to be more complex than was previously believed. The alcoholic-ketonic component of the "pyrethrins," designated as "pyrethrolone," has been found to be a heterogeneous mixture of closely related constituents (LaForge & Barthel 1944b). As a consequence of the separation and identification (LaForge & Barthel 1945) of the two main constituents of this mixture, pyrethrolone and cinerolone, the question of the relative toxicity of their chrysanthemum acid esters, the pyrethrins and cinerins, at once presents itself.

It is also of interest from the standpoints of insect toxicology and analytical procedures, as well as of usefulness in possible projects for the synthesis of an effective insecticide of this type, to determine the effect of changes in chemical structure on the relative toxicity of the compounds. The present study has resulted from these interests.

INSECTICIDAL MATERIALS.—LaForge & Barthel (1947) have prepared pyrethrins I and II and cinerins I and II by esterification of the active and inactive forms of natural pyrethrolone and cinerolone with active chrysanthemum monocarboxylic acid and chrysanthemum dicarboxylic acid monomethyl ester. The cinerins differ from the pyrethrins in that the side chain in the alcoholic-ketonic component is $-CH_2 \cdot CH:CH \cdot CH_3$ instead of $-CH_2 \cdot CH:CH \cdot CH:CH_2$.

To compare with these materials they have likewise prepared dihydro derivatives of pyrethrins I and II and cinerins I and II, wherein the double bond in the acid component has been saturated, and a tetrahydro derivative of pyrethrin I, wherein both double bonds in the pyrethrolone side chain have been saturated.

Thus there were 14 related compounds available for comparison of toxicity, as listed in table 1. These compounds were purified and analyzed, and sprays were prepared by dissolving the compounds in refined kerosene at selected concentrations. The pyrethrum standards of comparison were prepared from a kerosene extract of pyrethrum flowers, and chemical analysis (A.O.A.C. method) showed that 55 per cent of the total pyrethrins consisted of pyrethrin I and cinerin I.

PROCEDURE.—The tests were made by the turntable method on adult house flies, *Musca domestica* L., reared by standard procedure. Knock-down and mortality percentages were determined in as many replicated tests as possible with approximately 150 flies to each test.

Not all the materials were available at the same time and, because of the possibility of deterioration, they were tested in comparison with the same standard as soon as possible after their preparation. The interval was no longer than 3 days, except in the groups in which six replicates were made, when duplicates were made in each of three successive weeks. When not in use, the samples were kept in the refrigerator at 2° C., and there was no evidence of polymerization in any of them.

RESULTS.—The toxicity data are summarized in table 1, where they are grouped according to different populations of flies (series 1, 2, etc.). The flies were 2 days old and were usually rather resistant to the pyrethrum-extract sprays. In the case of the hydrogenated type II compounds all the material available for testing was used in preparing the sprays containing 1 and 2 mg. per milliliter, so that sprays of higher concentrations could not be tested.

DISCUSSION.—In this discussion the term "toxicity" refers solely to lethal effect. Knock-down percentages were generally much too high at the concentrations used to permit comparisons based on this effect. Knock-down of flies was complete for all the unsaturated compounds, but was appreciably lower for the hydrogenated type II compounds. Tetrahydropyrethrin I, though having low toxicity at 16 mg. per milliliter, still had high knock-down effect.

Although certain approximate relationships are immediately apparent from table 1, they may be put on a more quantitative

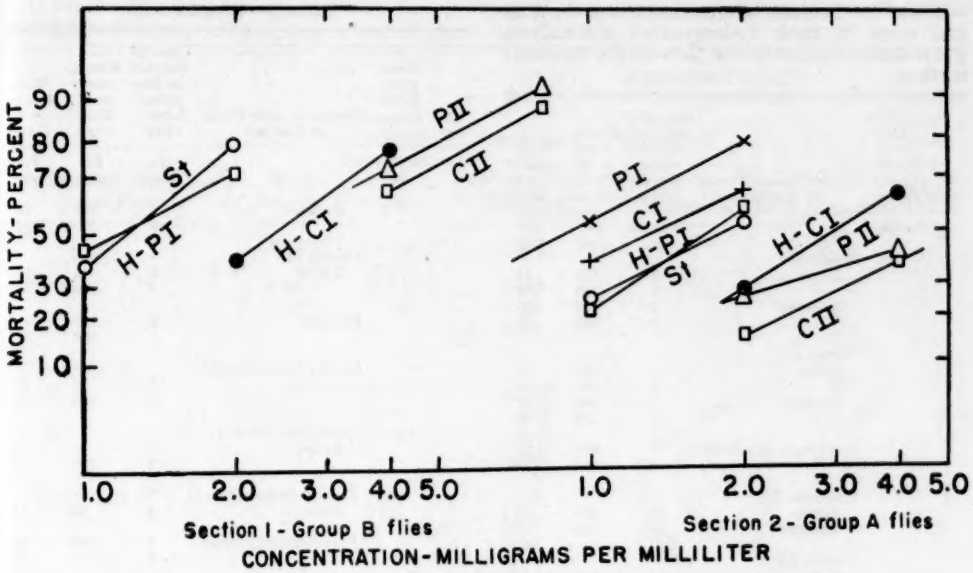


FIG. 1.—Toxicity curves for pyrethrins (P I and PII), cinerins (C I and C II), their dihyro ($H_2$) derivatives, and pyrethrum extract (St).

basis. To permit this, the results were plotted on log-probability paper and straight lines representing toxic action in the range studied were drawn, as shown in figure 1.

According to this method of testing, there were only slight, if any, differences in relative toxicity between the esters formed by the same acid with the optically active and racemic forms of the same alcohol-ketone. No differences at all were demonstrated in these tests. Therefore, for the purpose of the graph the general mean of mortalities for the two forms of the same compound was used, that is, the mean of 14 tests in series 1 and 12 tests in series 5. Because the small difference found in the resistance of the flies to the standard pyrethrum extract between the two series was well within the experimental error, the results may be considered as obtained on the same population of flies, designated group A, and thus may be directly compared.

In series 4 the testing of type II compounds at two concentrations, affords four more replicates with which to compare these materials more precisely with the pyrethrum standard, although in this case the mortality level is high. Since this population of flies, designated group B, showed much lower resistance than group A to the pyrethrum standard, the results must be considered separately and are so plotted in figure 1. Curves were also drawn for the hydrogenated type I compounds from the results with this group of flies, but the number of replications to determine each point is only two. When the general means of pyrethrin II and cinerin II are considered their difference is carried over the borderline of significance at odds of 19 to 1.

The relative toxicity of the compounds may be expressed by the ratios of the concentrations causing the same mortality of flies. Because of the differing ranges of toxic action obtained for the compounds, a single interpolated mortality level could not be used. However, concentrations corresponding to several mortality levels in figure 1 could be compared with those for the standard pyrethrum extract at the same levels for the same group of flies, and these ratios could be used for comparing the compounds among themselves. Such comparisons were made, and the data are given in table 2.

Because of the seeming divergency of the curves for some of the compounds, the comparisons were made at two or more mortality levels to obtain more general values. Slight extrapolation was necessary in a few cases, but the error was small.

**Table 1.—Toxicity of pyrethrins and cinerins and some of their hydrogenated derivatives, when tested against house flies by the turntable method.**

| Series | Tests with Each Compound | Compound and Form of Ketone | Concentration in Refined Kerosene | Knockdown in 25 Minutes | Mortality in 1 Day[1] |
|---|---|---|---|---|---|
| | *Number* | | *Mg. per ml.* | *Per Cent* | *Per Cent* |
| 1 | 7 | Pyrethrin I: | | | |
| | | Active | 1 | 100 | 54 |
| | | | 2 | 100 | 78 |
| | | Racemic | 1 | 100 | 50 |
| | | | 2 | 100 | 80 |
| | | Cinerin I: | | | |
| | | Active | 1 | 100 | 38 |
| | | | 2 | 100 | 60 |
| | | Racemic | 1 | 100 | 37 |
| | | | 2 | 100 | 68 |
| | | Pyrethrum oil extract | 1 | 100 | 28 |
| | | | 2 | 100 | 52 |
| 2 | 1 | Pyrethrin II: | | | |
| | | Active | 16 | 100 | 85 |
| | | Racemic | 16 | 100 | 75 |
| | | Cinerin II: | | | |
| | | Active | 16 | 100 | 81 |
| | | Racemic | 16 | 100 | 86 |
| 2 | 1 | Isodihydropyrethrin I: | | | |
| | | Active | 16 | 100 | 99 |
| | | Isodihydrocinerin I: | | | |
| | | Active | 16 | 100 | 99 |
| | | Tetrahydropyrethrin I: | | | |
| | | Active | 16 | 96 | 13 |
| | | Pyrethrum oil extract | 1 | 100 | 12 |
| | | | 2 | 100 | 49 |
| 3 | 1 | Pyrethrin II: | | | |
| | | Active | 4 | 100 | 18 |
| | | Racemic | 4 | 100 | 18 |
| | | Cinerin II: | | | |
| | | Active | 4 | 100 | 15 |
| | | Racemic | 4 | 100 | 17 |
| | | Isodihydropyrethrin I: | | | |
| | | Active | 4 | 100 | 91 |
| | | Isodihydrocinerin I: | | | |
| | | Active | 4 | 100 | 54 |
| | | Pyrethrum oil extract | 1 | 100 | 15 |
| | | | 2 | 100 | 46 |
| 4 | 2 | Pyrethrin II: | | | |
| | | Active | 4 | 100 | 74 |
| | | | 8 | 100 | 94 |
| | | Racemic | 4 | 100 | 73 |
| | | | 8 | 100 | 89 |
| | | Cinerin II: | | | |
| | | Active | 4 | 100 | 64 |
| | | | 8 | 100 | 86 |
| | | Racemic | 4 | 100 | 65 |
| | | | 8 | 100 | 90 |
| | | Isodihydropyrethrin I: | | | |
| | | Active | 1 | 99 | 43 |
| | | | 2 | 100 | 71 |
| 4 | 2 | Isodihydrocinerin I: | | | |
| | | Active | 2 | 100 | 39 |
| | | | 4 | 100 | 78 |
| | | Tetrahydropyrethrin I: | | | |
| | | Active | 16 | 88 | 16 |
| | | Pyrethrum oil extract | 1 | 100 | 37 |
| | | | 2 | 100 | 80 |
| 5 | 6 | Pyrethrin II: | | | |
| | | Active | 2 | 100 | 26 |
| | | | 4 | 100 | 42 |

**Table 1—(Continued)**

| Series | Tests with Each Compound | Compound and Form of Ketone | Concentration in Refined Kerosene | Knockdown in 25 Minutes | Mortality in 1 Day[1] |
|---|---|---|---|---|---|
| | *Number* | | *Mg. per ml.* | *Per cent* | *Per cent* |
| | | Racemic | 2 | 100 | 26 |
| | | | 4 | 100 | 41 |
| | | Cinerin II: | | | |
| | | Active | 2 | 99 | 12 |
| | | | 4 | 100 | 36 |
| | | Racemic | 2 | 100 | 18 |
| | | | 4 | 100 | 37 |
| | | Isodihydropyrethrin I: | | | |
| | | Active | 1 | 97 | 21 |
| | | | 2 | 100 | 57 |
| | | Isodihydrocinerin I: | | | |
| | | Active | 2 | 99 | 28 |
| | | | 4 | 100 | 63 |
| | | Tetrahydropyrethrin I: | | | |
| | | Active | 16 | 65 | 11 |
| | | Pyrethrum oil extract | 1 | 100 | 22 |
| | | | 2 | 100 | 52 |
| 6 | 2 | Isodihydropyrethrin II: | | | |
| | | Active | 1 | 80 | 3 |
| | | | 2 | 100 | 2 |
| | | Isodihydrocinerin II: | | | |
| | | Active | 1 | 19 | 3 |
| | | | 2 | 85 | 3 |
| 6 | 2 | Isodihydropyrethrin II: | | | |
| | | Racemic | 1 | 11 | 3 |
| | | | 2 | 93 | 4 |
| | | Pyrethrum oil extract | 1 | 100 | 24 |
| | | | 2 | 100 | 46 |

[1] A difference of 10% is significant at odds of 19 to 1 when 6 or 7 replications are made.

The ratios of toxicity obtained from such values were averaged with ratios obtained without extrapolation. In estimating the means the ratios were weighted according to the number of replications. The proportional standard errors for the estimated concentrations resulting from 12, 6, 4, and 2 replications were 5, 7, 8, and 12 per cent, respectively.

From these comparisons the following approximate relationships were found:

(1) Pyrethrin I was 4.3 times as toxic to house flies by this method as pyrethrin II.

(2) Cinerin I was 4.0 times as toxic as cinerin II.

(3) Pyrethrin I was 1.4 times as toxic as cinerin I.

(4) Pyrethrin II was 1.3 times as toxic as cinerin II.

(5) Pyrethrin I was 2.0 times and cinerin I was 1.4 times as toxic as the mixture of "pyrethrins" (55 per cent pyrethrin I and cinerin I) contained in the average pyrethrum-kerosene extract.

**Table 2.—Effect on toxicity to house flies of chemical changes in the structure of constituents of pyrethrum flowers.**

| Compound and Group of Flies | Mortality | Concentration Causing Indicated Mortality | Relative Toxicity | | | |
|---|---|---|---|---|---|---|
| | | | Compound to Pyrethrum Standard | Cinerin Compound to Pyrethrin Compound | Type II to Type I | Dihydro Derivative to Unsaturated Compound |
| | *Per cent* | *Mg. per ml.* | | | | |
| Pyrethrin I, A | 40 | 0.75 | 2.00 | | | |
| | 50 | .95 | 2.00 | | | |
| | | | Av. 2.00 | | | |
| Pyrethrin II: | | | | | | |
| A | 25 | 1.90 | 0.526 | | | |
| | 40 | 3.72 | .403 | | | |
| B | 70 | 3.60 | .458 | | | |
| | | | Av. .463 | | 0.23 | |
| Cinerin I, A | 40 | 1.07 | 1.40 | | | |
| | 50 | 1.40 | 1.36 | | | |
| | | | Av. 1.38 | 0.69 | | |
| Cinerin II: | | | | | | |
| A | 25 | 2.90 | .345 | | | |
| | 40 | 4.40 | .341 | | | |
| B | 70 | 4.57 | .361 | | | |
| | | | Av. .347 | .75 | .25 | |
| Isodihydropyrethrin I: | | | | | | |
| A | 25 | 1.08 | .926 | | | |
| | 40 | 1.46 | 1.027 | | | |
| | 50 | 1.77 | 1.073 | | | |
| B | 40 | 0.96 | 1.094 | | | |
| | 50 | 1.20 | 1.017 | | | |
| | 70 | 1.92 | .859 | | | |
| | | | Av. 1.00 | | | 0.50 |
| Isodihydrocinerin I: | | | | | | |
| A | 25 | 1.85 | .541 | | | |
| | 40 | 2.57 | .584 | | | |
| | 50 | 3.11 | .611 | | | |
| B | 40 | 2.03 | .517 | | | |
| | 50 | 2.40 | .508 | | | |
| | 70 | 3.40 | .485 | | | |
| | | | Av. .560 | .56 | | .41 |
| Pyrethrum standard: | | | | | | |
| A | 25 | 1.00 | 1.00 | | | |
| | 40 | 1.50 | 1.00 | | | |
| | 50 | 1.90 | 1.00 | | | |
| B | 40 | 1.05 | 1.00 | | | |
| | 50 | 1.22 | 1.00 | | | |
| | 70 | 1.65 | 1.00 | | | |
| Mean | | | | .67 | .24 | .46 |

(6) Pyrethrin II was 0.46 and cinerin II was 0.35 as toxic as this mixture.

(7) Isodihydropyrethrin I was 1.8 times as toxic as isodihydrocinerin I.

(8) Isodihydropyrethrin I was about as toxic and isodihydrocinerin I was about 0.6 as toxic as the pyrethrum standard.

(9) Pyrethrin I and cinerin I were about twice as toxic as their isodihydro derivatives.

(10) The toxicity of isodihydropyrethrin II and isodihydrociiserin II was negligible at the concentration levels of the pyrethrum standard tests.

(11) Tetrahydropyrethrin I had low toxicity as compared with the pyrethrum standard—less than 6.25 per cent as much. The general conclusions are as follows:

The esters formed by the same acid with

the optically active and racemic forms of the same alcohol-ketone did not differ in toxicity.

Replacement of the methyl group in the acid component with the monomethyl ester of the carboxyl group, that is, the change from type I to type II, was accompanied by a decrease in toxicity to about 25 per cent, whether the compound contained the pyrethrolone or the cinerolone side chain.

The shortening of the side chain of the alcohol-ketone component with the loss of one double bond, that is, the change from the pyrethrin structure to the cinerin structure, was accompanied by a decrease in toxicity to about 67 per cent, whether the acid component was that of type I, with its double bond either unsaturated or saturated, or of type II.

Hydrogenation at the double bond in the acid component, in either the pyrethrin I or the cinerin I molecule (at least in the compounds synthesized from the optically active alcohol-ketones), was accompanied by a decrease in toxicity to about half that of the unsaturated compound.

Replacement of the methyl group in the acid component with the monomethyl ester of the carboxyl group, together with hydrogenation at the double bond in the same component in either the pyrethrin or cinerin molecule, was accompanied by a great decrease in toxicity.

Saturation of both double bonds in the side chain of the alcohol-ketone component of pyrethrin I was accompanied by a decrease in toxicity to less than 6.25 per cent.

SUMMARY.—The relative toxicity to house flies of certain constituents of pyrethrum flowers and some of their hydrogenated derivatives was determined by the turntable method.

Both pyrethrin II and cinerin II were about 25 per cent as toxic as the corresponding type I compounds.

Both cinerins, as well as isodihydrocinerin I, were about 67 per cent as toxic as the corresponding pyrethrin compounds.

Both type I compounds were about twice as toxic as their isodihydro derivatives.

Pyrethrin I was about twice as toxic as the mixture of "pyrethrins" contained in the ordinary pyrethrum kerosene extract.

The toxicity of isodihydropyrethrin II and isodihydrocinerin II was negligible at the concentration levels of the pyrethrum standard tests.

Tetrahydropyrethrin I had low toxicity as compared with the pyrethrum standard —less than 6.25 per cent as much.—
**6-4-47.**

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Mr. Theodore L. Bissell, formerly Entomologist at the Georgia Experiment Station, Experiment, Georgia, has become a member of the staff of the Maryland Experiment Station, College Park, Maryland.

# The Toxicity of Organic Arsenicals[1]

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Inorganic arsenicals, such as lead and calcium arsenates, have been widely used as stomach insecticides and are effective against only those insects with biting mouth parts. On the other hand, many organic compounds, such as nicotine and pyrethrin, act mainly as contact poisons, are specific in action and easily decomposed. In the opinion of the author, it is highly probable that the introduction of certain organic radicals into inorganic arsenic compounds could not only enhance the effect of arsenic as stomach insecticides, but also create the contact poisoning effect which many organic compounds possess.

A search of literature reveals that besides paris green and its homologs which have been used extensively as insecticides (Dearborn 1936, 1937a, 1937b, 1937c, 1938, 1939, 1940; Bowen & Dearborn 1942; Fleming & Baker 1936; Fassig & Campbell 1937, Swingel *et al.* 1944), certain organic arsenicals have been tested as insecticides by the following workers: Brinley 1926, Walker & Mills 1927, Richardson & Smith 1923, Richardson & Seiferle 1938, McAllister & Van Leeuwen (1930), Lieske & Schepss 1930, Ginsburg 1935, Pokrovskii 1935, Guy 1938, Fink *et al.* 1936, 1938, Siegler *et al.* 1939, Swingle *et al.* 1944 and Bruce 1940.

Unfortunately very little is known about the relationship between the chemical constitution of these organic arsenic compounds and their toxicity to insects. Therefore, particular effort has been made in the present work to synthesize and collect as many of the organic arsenic compounds as possible in order to find the underlying principles governing their toxicity. The present research was stimulated by the hope of finding some highly promising insecticides and with the hope that it might serve as a guide to future research on this class of compounds.

MATERIALS AND METHODS.—1. *Chemicals:* Table 1 gives the name, source and purity of the chemicals used in the test.

2. *Insect:* The common confused flour beetle, *Tribolium confusum* Duval, was used in the following experiments in the study of both stomach and contact actions. Since Ginsburg (1935) employed it in a study of stomach poisons, it has been widely used in this manner (Dobroscky 1935; Fassig & Campbell 1937; Bissell 1943; King & Frear 1944) in addition to its standard use in fumigation experiment.

Stock cultures of the confused flour beetle were maintained in jars containing ample amounts of whole wheat flour enriched with 2 per cent of powdered dry yeast in a room with temperatures ranging from 25 to 27° C. and humidity ranging from 50 to 55 per cent; and the cultures of adults of known age were maintained under the above conditions, and separated from their immature progeny each month.

3. *Inert materials:* It has been found that a number of inert materials show insecticidal properties due to the desiccation of the insects. (Lepesme 1938, 1939; Chiu 1939a, 1939b; Poisson *et al.* 1939, 1940; Parkin 1944; Kalmus 1944; Alexander *et al.* 1944a, 1944b, 1944c, 1944d; Kitchener *et al.* 1943, 1945; Briscoe 1943; Wigglesworth 1944, 1944b). Eight different diluents were tested against the confused flour beetle; namely, sand, *Volclay, Argosite clay, Brunswick clay, Anderson clay, Derby clay,* diatomaceous earth, and *Celite;*[3] among them, the first two were used as diluents in testing contact poisons.

METHODS.—*Test as stomach insecticides.* The whole wheat flour and the chemicals to be tested were separately ground to pass through an 80 mesh sieve, after which 3 gms. of the whole wheat flour and the proper amount of the test substances were weighed on an analytical balance. They were thoroughly mixed and poured into two petri dishes (inside diameter: 9 cms.)

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[3] *Volclay* was obtained from American Colloid Co., Chicago, Ill. *Argosite clay, Brunswick clay, Anderson clay* and *Derby clay* was obtained from United States Clay Mines Corporation, Trenton, N. J. *Celite* was obtained from Johns-Manville Co. New York, N. Y. The origin of the diatomaceous earth and the sand was unknown.

**Table 1.—Source of chemicals.**

| Name of the Chemicals | Source[1] | Arsenic Content | |
|---|---|---|---|
| | | Calculated | Found[2] |
| Lead arsenate | I | | |
| Basic lead arsenate | II | | |
| Sodium fluoride | III | | |
| DDT | IV | | |
| Arsenious oxide, C.P. | V | | |
| Rotenone, C.P. | VI | | |
| o-Tolylarsonic acid | VII | 34.71 | 34.74 |
| p-Tolylarsonic acid | VII | 34.71 | 34.73 |
| m-Tolylarsonic acid | VII | 34.71 | 34.76 |
| o-Chlorophenylarsonic acid | VII | 31.72 | 31.66 |
| p-Chlorophenylarsonic acid | VII | 31.72 | 31.58 |
| m-Chlorophenylarsonic acid | VII | 31.72 | 31.88 |
| o-Nitrophenylarsonic acid | VII | 30.36 | 30.43 |
| p-Nitrophenylarsonic acid | VII | 30.36 | 30.47 |
| m-Nitrophenylarsonic acid | VII | 30.36 | 30.48 |
| o-Aminophenylarsonic acid | XI | 34.56 | 34.58 |
| p-Aminophenylarsonic acid | V | | |
| m-Aminophenylarsonic acid | VII | 34.56 | 34.63 |
| 2,4-Dinitrophenylarsonic acid | VII | 25.68 | 25.79 |
| 2,4-Diaminophenylarsonic acid | X | 32.32 | 32.21 |
| Ethylarsonic acid | V | | |
| n-Propylarsonic acid | V | | |
| p-Benzarsonic acid | V | | |
| Phenylarsonic acid | V | | |
| p-Hydroxyphenylarsonic acid | V | | |
| Sodium p-hydroxyphenylarsonate | V | | |
| 5-Nitro-1-naphthalenearsonic acid | X | 25.25 | 25.32 |
| 2-Nitro-1-naphthalenearsonic acid | VII | 25.25 | 25.23 |
| 8-Nitro-1-naphthalenearsonic acid | X | 25.25 | 25.31 |
| 4-Nitro-1-naphthalenearsonic acid | VII | 25.25 | 25.33 |
| 8-Nitro-2-naphthalenearsonic acid | VII | 25.25 | 25.13 |
| 6-Nitro-2-naphthalenearsonic acid | VII | 25.25 | 25.31 |
| 1-Nitro-2-naphthalenearsonic acid | VII | 25.25 | 25.38 |
| 4-Amino-1-naphthalenearsonic acid | XI | 28.08 | 28.13 |
| 5-Amino-1-naphthalenearsonic acid | X | 28.08 | 27.91 |
| 2-Amino-1-naphthalenearsonic acid | XI | 28.08 | 28.08 |
| 8-Amino-1-naphthalenearsonic acid (green) | X[3] | 28.08 | 27.63 |
| 8-Amino-1-naphthalenearsonic acid (dark green) | X[3] | 28.08 | 25.04 |
| 1-Amino-2-naphthalenearsonic acid | XI | 28.08 | 28.25 |
| 8-Amino-2-naphthalenearsonic acid | XI | 28.08 | 27.90 |
| 6-Amino-2-naphthalenearsonic acid | XI | 28.08 | 27.88 |
| Di (3-nitrophenyl) arsinic acid | VIII | 21.30 | 20.83 |
| Triphenylarsine | V | | |
| 2-Nitro-4-hydroxyphenylarsonic acid | VIII | 28.51 | 28.57 |
| 3-Nitro-4-methyl phenylarsonic acid | VIII | 28.73 | 28.60 |
| Diphenylarsinic acid | IX | 28.75 | 28.61 |
| m-Acetylphenylarsonic acid | VIII | 30.73 | 30.65 |
| 4-Arsono-N-2-thiazolebenzenesulfonamide | VIII | 21.30 | 20.97 |

(*continued in next column*)

[1] The source of these chemicals:
- I. Prepared by Dr. H. H. Shepard according to the method of Smith (1916).
- II. Manufactured by California Spray Chemical Corporation, Berkeley, California.
- III. Obtained from Geo. T. Walker Co., Minneapolis, Minn.
- IV. Obtained from Geigy Company, Inc., New York, N. Y.
- V. Obtained from Merck & Co., Inc., Rahway, N. J.
- VI. Obtained from Derris Incorporated, New York, N. Y.
- VII. These compounds were prepared by the author using known methods.
- VIII. Obtained from Dr. C. S. Hamilton's Laboratory, University of Nebraska.
- IX. Obtained from Dr. J. M. Ginsburg, Rutger's University.
- X. These compounds were prepared for the first time by the author and the method of preparation will be published separately.
- XI. For the first time these known aminoarylarsonic acids were prepared by the catalytic hydrogenation from their corresponding nitroarylarsonic acids with Raney nickel as catalyst under 40 pounds of pressure. The method of preparation will be published separately.

[2] All the arsenic analyses in this paper were made according to the procedure of Cislak & Hamilton (1930).

[3] This compound was made by two slightly different methods; one producing a dark green compound, the other producing a lighter green compound. Their purification was unsuccessful. The dark green compound is more impure than the other and probably takes up two molecules of oxygen right after its formation.

**Table 1.—(Continued)**

| Name of the Chemicals | Source[1] | Arsenic Content | |
|---|---|---|---|
| | | Calculated | Found[2] |
| o-Chlorophenylarsineoxide | VIII | 37.05 | 36.73 |
| p-Dimethylaminoazophenylarsonic acid | V | | |
| 2-Amino-4-hydroxyphenylarsonic acid | VIII | 29.87 | 29.84 |
| o-Isoamylaminophenylarsonic acid | VIII | 26.13 | 26.32 |
| 2-Nitrodiphenylamine-4-arsonic acid | VIII | 22.18 | 22.67 |
| 2-Chloro-5-aminophenylarsonic acid | VIII | 29.83 | 29.67 |
| 5,5'Dihydroxy-2,2'-dichloroarsenobenzene (Monohydrate) | VIII | 35.46 | 35.65 |
| p-2'-Hydroxy-propoxy-3-nitrophenylarsonic acid | VIII | 24.58 | 24.29 |
| Diphenylether o,o'-diarsonic acid | VIII | 35.88 | 35.94 |
| 3,4-Dimethoxy-5-acetylphenylarsonic acid | VIII | 24.66 | 25.06 |
| Dinitrate of 4,4'-bis-(β-hydroxypropoxy)-3,3'-dinitroarsenobenzene | VIII | 23.69 | 23.58 |
| 3-Nitro-4-carbo-iso-butoxy-hydroxyphenylarsonic acid | VIII | 20.64 | 20.91 |
| m-Acetylphenylarsineoxide | VIII | 35.71 | 35.88 |
| 2-Nitro-4-hydroxyphenylarsineoxide | VIII | 32.74 | 32.66 |
| p-N-4-(3-nitropyridyl)-aminophenylarsineoxide (monohydrate) | VIII | 23.22 | |
| N-4-(3-nitropyridyl)-arsanilic acid | VIII | 22.12 | 22.43 |
| 5,5'-Diamino-2,2'-dichloroarsenobenzene | VIII | 37.20 | 34.00 |
| 2-Chloro-5-Hydroxyphenylarsonic acid | VIII | 29.71 | 26.17 |
| p-Carboxyphenylarsinious acid | VIII | 32.60 | 31.93 |

in about equal amounts and distributed uniformly in a thin layer. Fifty adult beetles within the age range of 4 to 6 months were introduced into each of these petri dishes and stored under the conditions described for the stock cultures. Observations were made at desired intervals. Beetles which appeared to be dead were picked out with forceps without disturbing the live ones. Death of the beetles was determined by warming them near a 60-watt lamp for a short period. If there was no visible activity, the beetles were counted as dead. The number of deaths was recorded and the time for 50 per cent kill of the bettles was calculated by assuming that the mortality is proportional to time over the range between two mortality records, one above and one below the time for the 50 per cent kill. Two sets of checks were generally provided for the test at each concentration; one set provided with whole wheat flour only, and the other set, a starvation check, with neither food nor poison. Beetles selected for testing at any one concentration of the various poisons were chosen from a homogeneous culture and did not exceed a range of 2 weeks in age. Furthermore, the duplicate tests at one concentration were started on the same day. Three concentrations of the poisons in flour were tested in duplicate, namely 0.5, 2.0 and 10 per cent. At 0.5 and 10 per cent concentrations, two additional replicates were set

up, in which the insects used differed in age from the first two replicates. This was done in order to learn if some difference in age would affect the measure of toxicity of the stomach poisons.

*Test as contact insecticides.* Due to their differences in density and particle size, varying amounts of the inert materials were used so that a thin film would cover the bottom of the petri dishes. Twelve grams of sand, 6 grams each of *Volclay*, *Argosite clay*, *Brunswick clay*, *Anderson clay* and *Derby clay*, and 3 grams each of diatomaceous earth and *Celite* were employed. With the exception of the comparatively coarse sand, which was passed through a 100-mesh sieve before using, the other very fine inert materials were passed through an 80-mesh sieve before weighing in order to remove a few aggregates of the fine particles. After weighing, each material was roughly divided into four parts, transferred and distributed uniformly into a thin layer in four petri dishes, and 50 adult beetles of known age were introduced. One set of unfed insects was used for check comparison. The rest of the procedure was similar to the evaluation of these chemicals as stomach poisons.

After computing the results of the experiment with diluents, sand was chosen as the diluent for testing the toxicity of the poisons because it did not injure the beetles to any noticeable extent. Poisons mixed with sand, generally in the concentrations of 0.5 and 10 per cent were tested against the confused flour beetle. In addition, 2 per cent concentrations of the poisons were included in some of the tests. The experimental procedure was the same as in the test for stomach poisons except that 6 grams of sand, of the above specification, was used instead of 3 grams of whole wheat flour.

*Volclay* was used as another diluent for the chemicals tested in the study of contact poisons. The same procedure was used as in the case of sand except that 3 grams of *Volclay* were used. In a few instances, there were two additional duplicates, in which the beetles were different in age from those used in the first two replicates. This was done in order to learn whether some difference in age would affect the toxicity of these chemicals as contact poisons.

RESULTS.—The toxicity of the poisons in flour, sand and *Volclay* based on the time for 50 per cent kill of the confused flour beetle and arranged according to their structure and efficiency is given in table 2.

The data have further been examined by the method of the analysis of variance (Fisher 1936). As a general rule, those poisons which did not kill 50 per cent of the confused flour beetle within 30 days were not included in the analysis for the following reasons: (1) they had little value as insecticides, (2) the levels of significance obtained would not be accurate enough to permit a critical comparison of the effective poisons if the ineffective ones were included in the calculation.

The analyses of variance for the evaluation of the insecticidal properties of the inert materials alone, of the poisons mixed in flour and sand at 0.5, 2.0, and 10.0 per cent levels and of the poisons in *Volclay* at 2.0 and 10.0 per cent levels are tabulated in table 3.

The toxicity of the inert materials and the poisons in flour, in sand and in *Volclay* are given in tables 4, 5, 6 and 7 in the order of their relative toxicities based on the time for 50 per cent kill of the confused flour beetle. Only those materials which have been treated by the method of analysis of variance are included in these tables. The level of significance at the 5 per cent point was employed in setting up class values for sorting the poisons into various "grades" of toxicity. For example the class ranges for the 0.5 per cent poison in flour would be grade 1, 0.0–1.7; grade 2, 1.8–3.4; grade 3, 3.5–5.1; etc. and the class ranges for the 2.0 per cent poison in flour would be grade 1, 0.0–2.6; grade 2, 2.7–5.2; grade 3, 5.3–7.8; etc. The grades in the above tables, represent the quotient obtained by dividing the upper limit of the range of the time for 50 per cent kill by the level of significance at the five per cent point.

DISCUSSION AND SUMMARY.—The method for testing stomach insecticides used in this investigation, according to Hansberry (1943), is the best method for studying the interrelationships of time, dosage and mortality in a single experiment. It is quick, requires no special apparatus, and gives remarkably consistant results when replicated. However, it does not differentiate between stomach, contact and fumigating action.

The compounds tested in this experi-

**Table 2.—Toxicity of the poison in flour, sand and Volclay based on the time for 50 per cent kill of the confused flour beetle and arranged according to their structure and efficiency.**

| Poisons | Poison in Flour (in %) | | | | | Poison in Sand (in %) | | | Poison in *Volclay* (in %) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | | 2.0 | 10.0 | | 0.5 | 2.0 | 10.0 | 2.0 | 10.0 | |
| | Age I | Age II | Age I | Age I | Age II | Age I | Age I | Age I | Age I | Age I | Age II |
| I. *Standard Insecticides* | | | | | | | | | | | |
| DDT | 5.1 | 4.7 | 4.7 | 4.2 | 3.8 | 1.0 | — | 1.8 | — | 3.8 | 3.8 |
| Rotenone | 11.9 | 11.4 | — | — | 0.7 | 0.5 | — | 0.4 | — | 0.7 | 0.6 |
| Arsenious oxide | 10.4 | 8.4 | — | — | 4.9 | 8.7 | — | 1.7 | — | 4.5 | 9.7 |
| Sodium fluoride | * | * | 16.3 | 14.1 | 11.7 | 12.5 | — | 9.1 | — | 13.5 | — |
| Lead arsenate | * | * | ** | 16.7 | 14.0 | 16.1 | — | 7.1 | — | 12.2 | — |
| Basic lead arsenate | — | — | ** | 60.0 | 54.5 | — | — | — | — | 13.2 | — |
| II. *Phenylarsonic acid* | 12.4 | 16.4 | 9.8 | 1.6 | 1.5 | 1.1 | — | 1.2 | — | 2.3 | 2.3 |
| III. *Phenylarsonic acids containing methyl group* | | | | | | | | | | | |
| m-Tolylarsonic acid | * | * | 18.5 | 11.7 | 10.4 | 2.9 | — | 1.4 | — | 9.1 | 9.4 |
| 3-Nitro-4-methylphenylarsonic acid | * | * | 18.5 | 13.8 | 13.0 | 14.2 | — | 2.8 | — | 11.2 | — |
| p-Tolylarsonic acid | * | * | 22.4 | 13.1 | 11.6 | 13.7 | — | 1.6 | — | 11.5 | — |
| o-Tolylarsonic acid | * | * | 46.2 | 15.1 | 13.7 | 6.7 | — | 4.5 | — | 13.9 | — |
| IV. *Phenylarsonic acids containing chloro group* | | | | | | | | | | | |
| m-Chlorophenylarsonic acid | 10.3 | 17.7 | 9.6 | 1.6 | 1.8 | 0.9 | — | 0.6 | — | 2.6 | 2.4 |
| 2-Chloro-5-hydroxyphenylarsonic acid | 12.7 | 14.5 | 13.2 | 11.2 | 11.0 | 3.7 | — | — | — | — | — |
| o-Chlorophenylarsonic acid | 41.5 | 57.0 | 15.3 | 13.6 | 12.7 | 12.6 | — | 4.9 | — | 12.2 | — |
| p-Chlorophenylarsonic acid | * | * | 16.1 | 13.4 | 12.9 | 12.1 | — | 0.9 | — | 11.8 | — |
| 2-Chloro-5-aminophenylarsonic acid | * | * | 30.1 | 13.6 | 14.0 | 17.9 | — | — | — | 12.6 | — |
| V. *Phenylarsonic acids containing nitro group* | | | | | | | | | | | |
| 2,4-Dinitrophenylarsonic acid | 14.7 | 18.0 | 14.7 | 12.5 | 12.8 | 9.3 | — | — | — | 10.7 | — |
| m-Nitrophenylarsonic acid | 48.5 | 56.0 | 15.7 | 9.9 | 9.5 | 8.2 | — | 1.3 | — | 9.5 | 9.8 |
| 2-Nitro-4-hydroxyphenylarsonic acid | 85.5 | 90.6 | 16.1 | 11.3 | 10.5 | 10.0 | — | 1.5 | — | 10.6 | — |
| p-Nitrophenylarsonic acid | * | * | 16.8 | 14.0 | 13.0 | 15.9 | — | 1.5 | — | 11.8 | — |
| 3-Nitro-4-methylphenylarsonic acid | * | * | 18.5 | 13.8 | 13.0 | 14.2 | — | 2.8 | — | 11.4 | — |
| o-Nitrophenylarsonic acid | * | * | ** | 15.9 | 15.0 | 4.5 | — | 2.4 | — | 14.5 | — |
| VI. *Phenylarsonic acids containing amino group* | | | | | | | | | | | |
| 2,4-Diaminophenylarsonic acid | 12.2 | 13.8 | 11.4 | 9.0 | 9.7 | 4.6 | — | — | — | 9.4 | — |
| 2-Amino-4-hydroxyphenylarsonic acid monohydrate | 66.0 | 91.5 | 12.5 | 8.3 | 9.4 | 8.2 | — | — | — | 11.5 | — |
| o-Isoamylaminophenylarsonic acid | * | * | 17.8 | 12.9 | 12.3 | 14.2 | — | — | — | 11.3 | — |
| o-Aminophenylarsonic acid | * | * | 23.8 | 2.5 | 3.0 | 1.7 | — | 1.0 | — | 10.4 | 11.1 |
| 2-Chloro-5-amino phenylarsonic acid | * | * | 30.1 | 13.6 | 14.0 | 17.9 | — | — | — | 12.6 | — |
| m-Aminophenylarsonic acid | * | * | ** | 1.8 | 2.4 | 1.5 | — | 0.8 | — | 12.9 | 14.6 |
| p-Aminophenylarsonic acid | * | * | ** | 16.7 | 14.3 | 13.1 | — | 1.1 | — | 14.0 | — |
| VII. *o-Substituted phenylarsonic acids* | | | | | | | | | | | |
| 2,4-Diaminophenylarsonic acid | 12.2 | 13.8 | 11.4 | 9.0 | 9.7 | 4.6 | — | — | — | 9.4 | — |
| 2,4-Dinitrophenylarsonic acid | 14.7 | 18.0 | 14.7 | 12.5 | 12.8 | 9.3 | — | — | — | 10.7 | — |
| o-Chlorophenylarsonic acid | 41.5 | 57.0 | 15.3 | 13.6 | 12.7 | 12.6 | — | 4.9 | — | 12.2 | — |
| 2-Amino-4-hydroxyphenylarsonic acid monohydrate | 66.0 | 91.5 | 12.5 | 8.3 | 9.4 | 8.2 | — | — | — | 11.5 | — |
| 2-Nitro-4-hydroxyphenylarsonic acid | 85.5 | 90.6 | 16.1 | 11.3 | 10.5 | 10.0 | — | 1.5 | — | 10.6 | — |
| o-Isoamylaminophenylarsonic acid | * | * | 17.8 | 12.9 | 12.3 | 14.2 | — | — | — | 11.3 | — |
| o-Aminophenylarsonic acid | * | * | 23.8 | 2.5 | 3.0 | 1.7 | — | 1.0 | — | 10.4 | 11.1 |
| 2-Chloro-5-aminophenylarsonic acid | * | * | 30.1 | 13.6 | 14.0 | 17.9 | — | — | — | 12.6 | — |
| o-Tolylarsonic acid | * | * | 46.2 | 15.1 | 13.7 | 6.3 | — | 4.5 | — | 13.9 | — |
| o-Nitrophenylarsonic acid | * | * | ** | 15.9 | 15.0 | 4.5 | — | 2.4 | — | 14.5 | — |
| VIII. *p-Substituted phenylarsonic acids* | | | | | | | | | | | |
| Sodium p-hydroxyphenylarsonate | 67.5 | 84.0 | 16.4 | 13.3 | 12.2 | 12.5 | — | 7.6 | — | 12.4 | — |
| p-Chlorophenylarsonic acid | * | * | 16.1 | 13.4 | 12.9 | 12.1 | — | 0.9 | — | 11.8 | — |
| p-Nitrophenylarsonic acid | * | * | 16.8 | 14.0 | 13.0 | 15.9 | — | 1.5 | — | 11.8 | — |
| p-Tolylarsonic acid | * | * | 22.4 | 13.1 | 11.6 | 13.7 | — | 1.6 | — | 11.5 | — |
| N-4-(3-Nitropyridyl)-arsanilic acid | * | * | 29.8 | 15.3 | 14.9 | — | — | — | — | — | — |
| p-Benzarsonic acid | — | — | 61.5 | 20.8 | 16.9 | 20.6 | — | 15.2 | — | 13.7 | — |
| p-Aminophenylarsonic acid | * | * | ** | 16.7 | 14.3 | 13.1 | — | 1.1 | — | 14.0 | — |
| 3-Nitro-4-carbo-isobutoxy-hydroxy-phenylarsonic acid | — | — | ** | 49.3 | — | — | — | — | — | — | — |
| p-Hydroxyphenylarsonic acid | — | — | ** | *** | 22.5 | 17.9 | — | 2.9 | — | 14.3 | — |
| p-Dimethylaminoazophenylarsonic acid | — | — | ** | 64.3 | 53.3 | — | — | — | — | 14.1 | — |
| 4-Arsono-N-2-thiazole-benzene-sulfonamide | — | — | ** | *** | *** | — | — | — | — | — | — |
| p-2'-Hydroxy-propoxy-5-acetyl-phenylarsonic acid | — | — | ** | *** | — | — | — | — | — | — | — |
| 3,4-Dimethoxy-5-acetylphenylarsonic acid | — | — | ** | *** | — | — | — | — | — | — | — |

* More than 97.0.
** More than 74.0.
*** More than 69.0.
**** Dead beetles did not exceed 4 per cent in any cases over a period of 100 days.

**Table 2—(Continued)**

| Poisons | Poison in Flour (in %) | | | | | Poison in Sand (in %) | | | Poison in *Volclay* (in %) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | | 2.0 | 10.0 | | 0.5 | 2.0 | 10.0 | 2.0 | 10.0 | |
| | Age I | Age II | Age I | Age I | Age II | Age I | Age I | Age I | Age I | Age I | Age II |
| IX. *m-Substituted phenylarsonic acids* | | | | | | | | | | | |
| m-Chlorophenylarsonic acid | 10.3 | 17.7 | 9.6 | 1.6 | 1.8 | 0.9 | — | 0.6 | — | 2.6 | 2.4 |
| m-Nitrophenylarsonic acid | 48.5 | 56.0 | 15.7 | 9.9 | 9.5 | 8.2 | — | 1.3 | — | 9.5 | 9.8 |
| m-Tolylarsonic acid | * | * | 18.5 | 11.7 | 10.4 | 2.9 | — | 1.4 | — | 9.1 | 9.4 |
| 3-Nitro-4-methylphenylarsonic acid | * | * | 18.5 | 13.8 | 13.0 | 14.2 | — | 2.8 | — | 11.2 | — |
| 2-Nitrodiphenylamine-4-arsonic acid | * | * | 18.2 | 14.9 | 14.8 | 15.0 | — | — | — | 12.4 | — |
| m-Acetylphenylarsonic acid | — | — | 55.7 | 17.2 | 15.1 | 2.0 | — | — | — | 12.9 | — |
| m-Aminophenylarsonic acid | * | * | ** | 1.8 | 2.4 | 1.5 | — | 0.8 | — | 12.9 | 14.6 |
| 3-Nitro-4-carbo-isobutoxy-hydroxyphenylarsonic acid | — | — | ** | 49.3 | — | — | — | — | — | — | — |
| 3,4-Dimethoxy-5-Acetylphenylarsonic acid | — | — | ** | *** | — | — | — | — | — | — | — |
| X. *Phenylarsonic acids and their arsineoxides* | | | | | | | | | | | |
| o-Chlorophenylarsonic acd | 41.5 | 57.0 | 15.3 | 13.6 | 12.7 | 12.6 | — | 4.9 | — | 12.2 | — |
| o-Chlorophenylarsineoxide | — | — | ** | 22.0 | 22.2 | — | — | — | — | 11.8 | — |
| m-Acetylphenylarsonic acid | — | — | 55.7 | 17.2 | 15.1 | 2.0 | — | — | — | 12.9 | — |
| m-Acetylphenylarsineoxide | * | * | 21.6 | 15.6 | 15.7 | — | — | — | — | — | — |
| 2-Nitro-4-hydroxyphenylarsonic acid | 85.5 | 90.6 | 16.1 | 11.8 | 10.5 | 10.0 | — | 1.5 | — | 10.6 | — |
| 2-Nitro-4-hydroxyphenylarsine-oxide | * | * | 23.8 | 12.1 | 12.6 | — | — | — | — | — | — |
| N-4-(3-Nitropyridyl)-arsanilic acid | * | * | 29.8 | 15.3 | 14.9 | — | — | — | — | — | — |
| p-N-4-(3-Nitropyridyl)-amino-phenylarsineoxide monohydrate | — | — | 18.7 | — | — | — | — | — | — | — | — |
| XI. *Phenylarsonic acids and their arsenobenzenes* | | | | | | | | | | | |
| 2-Chloro-5-amino-phenylarsonic acid | * | * | 30.1 | 13.6 | 14.0 | 17.9 | — | — | — | 12.6 | — |
| 2,2′-Dichloro-5,5′-diaminoarsenobenzene | * | * | 27.5 | 17.8 | — | — | — | — | — | — | — |
| 2-Chloro-5-hydroxyphenylarsonic acid | 12.7 | 14.5 | 13.2 | 11.2 | 11.0 | 3.7 | — | — | — | — | — |
| 2,2′-Dichloro-5,5′-dihydroxy-arsenobenzene monohydrate | 16.3 | 20.2 | 15.7 | 13.2 | 13.2 | 3.2 | — | — | — | 10.1 | — |
| XII. *Naphthalenearsonic acids containing Nitro group* | | | | | | | | | | | |
| 2-Nitro-1-naphthalenearsonic acid | 13.9 | 13.3 | 13.0 | 7.7 | 7.1 | 0.7 | 0.4 | — | 10.5 | 7.3 | 8.4 |
| 1-Nitro-2-naphthalenearsonic acid | 13.4 | 14.3 | 13.0 | 10.7 | 10.9 | 5.3 | 1.9 | 4.9 | 11.5 | 10.2 | — |
| 4-Nitro-1-naphthalenearsonic acid | 13.8 | 15.1 | 13.5 | 13.9 | 12.0 | 4.8 | 4.7 | 3.5 | 13.0 | 12.0 | — |
| 8-Nitro-2-naphthalenearsonic acid | 17.2 | 27.0 | 14.9 | 14.7 | 14.2 | 17.7 | 14.9 | 12.6 | 12.4 | 13.3 | — |
| 5-Nitro-1-naphthalenearsonic acid | 51.0 | 35.3 | 15.3 | 15.0 | 13.9 | 17.1 | 1.9 | 1.8 | 11.9 | 13.3 | — |
| 6-Nitro-2-naphthalenearsonic acid | 48.8 | 37.9 | 16.8 | 13.9 | 12.9 | 15.0 | 13.9 | 11.3 | 11.8 | 12.5 | — |
| 8-Nitro-1-naphthelearsonic acid | * | * | 44.5 | 15.0 | 13.8 | 14.6 | 3.3 | — | 12.5 | 14.9 | — |
| XIII. *Naphthalenearsonic acids containing amino group* | | | | | | | | | | | |
| 2-Amino-1-naphthalenearsonic acid | 10.2 | 12.1 | 9.5 | 3.7 | 3.0 | 1.6 | 1.3 | — | 10.4 | 5.7 | 8.1 |
| 4-Amino-1-naphthalenearsonic acid | 15.2 | 18.7 | 11.3 | 2.6 | 2.6 | 1.8 | 1.5 | 1.6 | 10.7 | 8.8 | 8.0 |
| 1-Amino-2-naphthalenearsonic acid | 18.3 | 25.5 | 13.9 | 11.6 | 10.3 | 13.0 | 2.9 | 2.1 | 11.1 | 10.3 | — |
| 8-Amino-1-naphthalenearsonic acid (green) | 25.1 | 32.8 | 17.1 | 11.2 | 11.9 | 11.2 | 5.2 | — | 11.5 | 10.4 | — |
| 6-Amino-2-naphthalenearsonic acid | * | * | 18.0 | 14.7 | 12.7 | 14.3 | 12.1 | — | 10.9 | 11.5 | — |
| 5-Amino-1-naphthalenearsonic acid | * | * | 17.8 | 15.0 | 13.4 | 15.3 | 13.5 | — | 12.2 | 12.5 | — |
| 8-Amino-2-naphthalenearsonic acid | * | * | 18.3 | 14.5 | 13.2 | 16.4 | 2.0 | — | 12.0 | 11.9 | — |
| 8-Amino-1-naphthalenearsonic acid (dark green) | * | * | 33.9 | 15.7 | 15.5 | 17.1 | 15.6 | — | 12.5 | 12.6 | — |
| XIV. *Checks* | | | | | | | | | | | |
| Starvation | 23.1 | 26.1 | 27.6 | 24.3 | 22.9 | 22.6 | 23.5 | 23.5 | 23.5 | — | 26.5 |
| Sand only | | | | | | 21.1 | 21.6 | 21.5 | | | |
| Volclay only | | | | | | | | | 13.6 | 13.1 | 15.4 |
| Flour only | **** | **** | **** | **** | **** | | | | | | |

ment are solids which in many cases possess high melting points. The fumigating action could not play an important role. Therefore, only stomach and contact effects could be expected from these poisons. In order to obtain a possible differentiation of insecticidal action, experiments were set up to test the contact effect. In a study of the use of inert dust as insecticides, Alexander *et al.* (1944b) used a method in which 20 or 30 granary weevils were placed in a glass dish of 5 cm. diameter with sufficient dust but with no wheat. They pointed out that an important aspect of the test is that starving insects do not eat inert dust under these conditions. If the flour beetles behave in the same way, it could be expected that the method used in studying the effect of contact poisons in this investigation

**Table 3.—The analyses of variance for the evaluation of the insecticidal values of the inert materials and of the poisons in flour, in sand and in Volclay.**

| Variance Due to | | Replications | Kinds of Poisons | Age Levels | Interaction Between Kinds of Poisons and Ages | L. S.[3] (5%) |
|---|---|---|---|---|---|---|
| 0.5% Poison in flour[1] | D. F.[3] | 1 | 19 | 1 | 19 | 1.7 |
| | M. S.[3] | 1.95 | 111.52** | 154.29** | 9.92 | |
| 2.0% Poison in flour[2] | D. F. | 1 | 43 | | | 2.6 |
| | M. S. | 1.43 | 53.92** | | | |
| 10.0% Poison in flour[1] | D. F. | 1 | 51 | 1 | 51 | 1.2 |
| | M. S. | 2.61 | 78.05** | 29.18** | 1.03 | |
| 0.5% Poison in sand[2] | D. F. | 1 | 52 | | | 2.0 |
| | M. S. | 5.89* | 74.82** | | | |
| 2.0% Poison in sand[2] | D. F. | 1 | 14 | | | 1.9 |
| | M. S. | 0.14 | 67.48** | | | |
| 10.0% Poison in sand[2] | D. F. | 1 | 33 | | | 1.1 |
| | M. S. | 2.08* | 42.50** | | | |
| 2.0% Poison in Volclay[2] | D. F. | 1 | 14 | | | 0.8 |
| | M. S. | 0.39 | 1.28** | | | |
| 10.0% Poison in Volclay[2] | D. F. | 1 | 54 | | | 1.2 |
| | M. S. | 0.66 | 20.27** | | | |
| 10.0% Poison in Volclay[1] | D. F. | 1 | 11 | 1 | 11 | 1.2 |
| | M. S. | 1.30 | 60.60** | 9.28** | 2.63** | |
| Inert Materials | D. F. | 3 | 8 | | | 0.7 |
| | M. S. | 0.03 | 407.32** | | | |

[1] Including two age groups of insects.
[2] One age group of insects only.
[3] D. F. represents the degree of freedom, M. S. represents the mean square and L. S. (5%) represents the level of significance at the 5 per cent point. The mean square values marked with ** exceeded the 1 per cent point, which means that they are "highly significant"; those marked with * exceeded the 5 per cent point, and are "significant," and the others did not reach either the 1 or 5 per cent points.

would be very useful, provided that the diluent itself did not injure the beetles. The data (Table 6) do indicate that this method is very satisfactory. It was found (Table 4) that sand of certain sizes was the best diluent among the materials tested for it did not injure the beetles to any noticeable extent and its use as a diluent revealed the slightest contact action of a poison. This may be partly explained by the following conditions: 1. Sand is not sufficiently fine nor does it have sufficient adhesive properties to scratch the lipoid layer of the epicuticle of the beetle, and consequently does not promote the loss of water from insect body which would cause death. 2. Because of its relative coarseness, sand has a smaller surface area for a given weight than do those materials consisting of finer particles. When the concentration of the poison is measured on a weight basis, the poison in a coarser diluent would be more effective than that in a finer diluent at the same concentration.

For comparison, *Volclay* was used as a carrier, although it is not a good carrier for contact insecticides and also injures the beetles. In using it as a diluent, only a few poisons, such as rotenone, phenylarsonic acid, m-chlorophenylarsonic acid, showed any strong contact poisoning effects (Table 7). Some of the poisons, such as

**Table 4.—The toxicity of inert materials based on the time for 50 per cent kill of the confused flour beetle[1] and arranged in grades according to their toxicities. (The level of significance at the 5 per cent point is 0.6 days.)**

| Inert Materials | Time Range in Days for 50 Per Cent Kill | Grade[2] |
|---|---|---|
| *Celite* | 1.3– 1.8 | 3 |
| Diatomaceous Earth | 1.9– 2.4 | 4 |
| *Brunswick Clay* | 1.9– 2.4 | 4 |
| *Anderson Clay* | 2.5– 3.0 | 5 |
| *Derby Clay* | 6.1– 6.6 | 11 |
| *Volclay* | 13.9–14.4 | 24 |
| *Argosite Clay* | 16.9–17.4 | 29 |
| Sand | 24.1–24.6 | 41 |
| Starvation Check | 26.5–27.0 | 45 |

[1] Adult beetles of 168–175 days old were used.
[2] The grade in this table and in the following tables represents the quotient obtained by dividing the upper limit of the range of the time for 50 per cent kill by the level of significance at the 5 per cent point. This is the only table which gives the time range in days for 50 per cent kill. The following tables will not include this item due to the shortage of space.

**Table 5.—The toxicity of 0.5, 2.0 and 10.0 per cent poison in flour based on the time for 50 per cent kill of the confused flour beetle[1] and arranged in grades[2] according to their toxicities.**

| Poisons | Per Cent of Poison | | | | |
|---|---|---|---|---|---|
| | 0.5 | | 2.0 | 10.0 | |
| Age | I | II | I | I | II |
| Rotenone[3] | 7 | 7 | — | — | 1 |
| m-Chlorophenylarsonic acid | 7 | 11 | 4 | 2 | 2 |
| m-Aminophenylarsonic acid | | | | 2 | 2 |
| Phenylarsonic acid | 8 | 10 | 4 | 2 | 2 |
| o-Aminophenylarsonic acid | | | 10 | 3 | 3 |
| 4-Amino-1-naphthalenearsonic acid | 9 | 11 | 5 | 3 | 3 |
| 2-Amino-1-naphthalenearsonic acid | 6 | 8 | 4 | 4 | 3 |
| DDT | 3 | 3 | 2 | 4 | 4 |
| Arsenious oxide[3] | 7 | 5 | — | — | 5 |
| 2-Nitro-1-naphthalenearsonic acid | 9 | 8 | 5 | 7 | 6 |
| 2-Amino-4-hydroxyphenylarsonic acid monohydrate | | | 5 | 7 | 8 |
| 2,4-Diaminophenylarsonic acid | 8 | 9 | 5 | 8 | 9 |
| m-Nitrophenylarsonic acid | | | 7 | 9 | 8 |
| 1-Nitro-2-naphthalenearsonic acid | 8 | 9 | 5 | 9 | 10 |
| m-Tolylarsonic acid | | | 8 | 10 | 9 |
| 1-Amino-2-naphthalenearsonic acid | 11 | 15 | 6 | 10 | 9 |
| 2-Nitro-4-hydroxyphenylarsonic acid | | | 10 | 10 | 9 |
| 8-Amino-1-naphthalenearsonic acid (Green) | 15 | 20 | 7 | 10 | 10 |
| 2-Chloro-5-hydroxyphenylarsonic acid | 8 | 9 | 6 | 10 | 10 |
| p-Tolylarsonic acid | | | 9 | 11 | 10 |
| 2,4-Dinitrophenylarsonic acid | 9 | 11 | 6 | 11 | 11 |
| Ethylarsonic acid | 9 | 10 | 6 | 11 | 11 |
| o-Isoamyl-aminophenylarsonic acid | | | 7 | 11 | 11 |
| 5,5′-Dihydroxy-2,2′-dichlorarseno-benzene monohydrate | 10 | 12 | 7 | 11 | 11 |
| 2-Nitro-4-hydroxyphenylarsineoxide | | | 10 | 11 | 11 |
| 4-Nitro-1-naphthalenearsonic acid | 9 | 9 | 6 | 12 | 10 |
| Sodium fluoride | | | 7 | 12 | 10 |
| o-Chlorophenylarsonic acid | | | 6 | 12 | 11 |
| p-Chlorophenylarsonic acid | | | 7 | 12 | 11 |
| p-Nitrophenylarsonic acid | | | 7 | 12 | 11 |
| Sodium p-hydroxyphenylarsonate | | | 7 | 12 | 11 |
| 6-Nitro-2-naphthalenearsonic acid | | | 7 | 12 | 11 |
| 3-Nitro-4-methylphenylarsonic acid | | | 8 | 12 | 11 |
| 2-Chloro-5-aminophenylarsonic acid | | | 12 | 12 | 12 |
| n-Propylarsonic acid | 8 | 8 | 6 | 13 | 11 |
| 8-Amino-2-naphthalenearsonic acid | | | 8 | 13 | 11 |
| 6-Amino-2-naphthalenearsonic acid | | | 7 | 13 | 11 |
| o-Tolylarsonic acid | | | | 3 | 12 |
| 5-Nitro-1-naphthalenearsonic acid | | | 6 | 13 | 12 |
| 8-Nitro-1-naphthalenearsonic acid | | | | 13 | 12 |
| 8-Nitro-2-naphthalenearsonic acid | 11 | 16 | 6 | 13 | 12 |
| 5-Amino-1-naphthalenearsonic acid | | | 7 | 13 | 12 |
| Diphenylarsinic acid | 13 | 14 | 7 | 13 | 12 |
| 2-Nitro-diphenylamine-4-arsonic acid | | | 7 | 13 | 13 |
| N-4-(3-Nitro-pyridyl)-arsanilic acid | | | 12 | 13 | 13 |
| m-Acetylphenylarsineoxide | | | 9 | 13 | 14 |
| Lead arsenate | | | | 14 | 12 |
| p-Aminophenylarsonic acid | | | | 14 | 12 |
| o-Nitrophenylarsonic acid | | | | 14 | 13 |
| 8-Amino-1-naphthalenearsonic acid (Dark green) | | | | 14 | 13 |
| Di-(3-nitrophenyl)-arsinic acid | | | | 14 | 13 |
| m-Acetylphenylarsonic acid | | | | 15 | 13 |
| Dinitrate of 4,4′-bis-β-hydroxy propoxy-3,3′-dinitroarsenobenzene | | | 10 | 15 | — |
| 5,5′-Diamino-2,2′-dichloroarseno-benzene[3] | | | 11 | 15 | — |
| p-Benzarsonic acid | | | | 18 | 15 |
| o-Chlorophenylarsineoxide | | | | 19 | 19 |
| p-N-4-(3-nitropyridyl)aminophenyl-arsineoxide monohydrate | | | 8 | — | — |
| Check (Starvation)[4] | 14 | 16 | 11 | 21 | 20 |

[1] Two age groups of beetles were used in the 0.5 per cent experiments. Age I group consisted of adult beetles 140 to 147 days old and Age II group consisted of adults 156 to 163 days old. Adult beetles 127 to 139 days were used in the 2.0 per cent of poison. Two age groups of beetles were used in the 10.0 per cent of poison. Age I group consisted of adult beetles 123 to 145 days old and Age II group of adult beetles 134 to 141 days old.

[2] The grades, in this table and in the following tables, can be used only to evaluate the toxicities of the different compounds at each particular concentration. No attempt was made to compare them at different concentrations.

[3] These data on 10.0 per cent poison were not analyzed because only one age group of insects was used. The dashes in this and the following tables indicate that no experiment has been done in that particular case.

[4] Dead beetles did not exceed four per cent in any cases over a period of 100 days when the beetles were fed on flour alone.

o-nitrophenylarsonic acid and 8-nitro-1-naphthalenearsonic acid, were toxic when used with sand but in *Volclay* actually reduced the rate of mortality below that of the *Volclay* used alone. This verifies the results obtained by Wilson and his associates (Wilson & Janes 1942a, 1942b; Wilson & Bender 1942; Campau & Wilson 1944; Wilson *et al.* 1944; Janes & Wilson *et al.* 1944; Turner 1943; and Robinson & Hatch 1944) who found that the selection of a diluent for rotenone is very important in the control of aphids and other insects. Siegler & Smith (1942) also found that the use of bentonite and hydrated lime as diluent would decrease the toxicity of phenothiazine to the codling moth larvae.

The results (Tables 5, 6, 7) indicate that most of the poisons tested possess contact poisoning effects, that flour is not a good carrier for contact insecticides and that these poisons are not quick-acting stomach insecticides against confused flour beetle. Therefore, the method used for testing stomach poisons was not satisfactory because of the contact poisoning. The toxicity of the poisons obtained by this method is considered as a combined effect of stomach and contact action. There are poisons, such as n-propylphenylarsonic acid, which are more effective at a lower concentration in flour than at a higher concentration. This could be due either to a repellent action at high concentrations or to a difference in effect upon beetles of different ages. There are also a number of poisons, such as some of the nitronaphthalenearsonic acids, in which the increase in concentration in flour does not produce an appreciable change in toxicity. They act very slowly in flour but quickly in sand. This suggests that they are mainly stomach poisons when they are mixed with flour and are repellent to the beetle at high concentrations. It is very interesting to note that 1-nitro-2-naphthalenearsonic acid in sand is much less toxic at the 10 per cent than at the 2 per cent level even when the beetles used in the test were in the same age range. It may be due to the fact that at high concentration the beetles are quickly paralyzed and turn over on their backs so that they are protected from further poisoning by their elytra.

Although three concentrations were generally used in testing the insecticidal values of these poisons, no attempt was

**Table 6.—The toxicity of 0.5, 2.0 and 10.0 per cent poison in sand based on the time for 50 per cent kill of the confused flour beetle[1] and arranged in grades according to their toxicities.**

| Poison | Per Cent of Poison | | |
|---|---|---|---|
| | 0.5 | 2.0 | 10.0 |
| DDT | 1 | — | 2 |
| Rotenone | 1 | — | 1 |
| m-Chlorophenylarsonic acid | 1 | — | 1 |
| o-Aminophenylarsonic acid | 1 | — | 1 |
| m-Aminophenylarsonic acid | 1 | — | 1 |
| Phenylarsonic acid | 1 | — | 2 |
| 2-Nitro-1-naphthalenearsonic acid | 1 | 1 | — |
| 4-Amino1-naphthalenearsonic acid | 1 | 1 | 2 |
| 2-Amino-1-naphthalenearsonic acid | 1 | 1 | — |
| m-Acetylphenylarsonic acid | 1 | — | — |
| m-Tolylarsonic acid | 2 | — | 2 |
| 5,5′-Dihydroxy-2,2′-dichloroarsenobenzene monohydrate | 2 | — | — |
| 2-Chloro-5-hydroxyphenylarsonic acid | 2 | — | — |
| o-Nitrophenylarsonic acid | 3 | — | 3 |
| 2,4-Diaminophenylarsonic acid | 3 | — | — |
| 4-Nitro-1-naphthalenearsonic acid | 3 | 3 | 4 |
| 1-Nitro-2-naphthalenearsonic acid | 3 | 2 | 5 |
| o-Tolylarsonic acid | 4 | — | 5 |
| Arsenious oxide | 5 | — | 2 |
| m-Nitrophenylarsonic acid | 5 | — | 2 |
| 2,4-Dinitrophenylarsonic acid | 5 | — | — |
| 2-Nitro-4-hydroxyphenylarsonic acid | 5 | — | 2 |
| 2-Amino-4-hydroxyphenylarsonic acid monohydrate | 5 | — | — |
| 8-Amino-1-naphthalenearsonic acid (green) | 6 | 3 | — |
| Diphenylarsinic acid | 6 | — | — |
| Sodium fluoride | 7 | — | 9 |
| p-Tolylarsonic acid | 7 | — | 2 |
| o-Chlorophenylarsonic acid | 7 | — | 5 |
| p-Chlorophenylarsonic acid | 7 | — | 1 |
| p-Aminophenylarsonic acid | 7 | — | 1 |
| Ethylarsonic acid | 7 | — | 7 |
| n-Propylarsonic acid | 7 | — | 3 |
| Sodium p-hydroxyphenylarsonate | 7 | — | 7 |
| 1-Amino-2-naphthalenearsonic acid | 7 | 2 | 2 |
| p-Nitrophenylarsonic acid | 8 | 2 | 2 |
| 8-Nitro-1-naphthalenearsonic acid | 8 | 9 | — |
| 6-Nitro-2-naphthalenearsonic acid | 8 | 8 | 11 |
| 5-Amino-1-naphthalenearsonic acid | 8 | 8 | — |
| 6-Amino-2-naphthalenearsonic acid | 8 | 7 | — |
| 3-Nitro-4-methylphenylarsonic acid | 8 | — | 3 |
| o-Isoamyl-aminophenylarsonic acid | 8 | — | — |
| 2-Nitro-diphenylamine-4-arsonic acid | 8 | — | — |
| Dinitrate of 4,4′-bis-(β-hydroxypropoxy)-3,3′-dinitroarsenobenzene | 8 | — | — |
| Lead arsenate | 9 | — | 7 |
| p-Hydroxyphenylarsonic acid | 9 | — | 3 |
| 5-Nitro-1-naphthalenearsonic acid | 9 | 2 | 2 |
| 8-Nitro-2-naphthalenearsonic acid | 9 | 9 | 12 |
| 8-Amino-1-naphthalenearsonic acid (Dark green) | 9 | 9 | — |
| 8-Amino-2-naphthalenearsonic acid | 9 | — | — |
| Di-(3-nitrophenyl)-arsinic acid | 9 | — | 15 |
| 2-Chloro-5-aminophenylarsonic acid | 9 | — | — |
| Triphenylarsine | 10 | — | 14 |
| p-Benzarsonic acid | 11 | — | 14 |
| Check (sand only) | 11 | 12 | 20 |

[1] Adult beetles 157 to 171 days old were used.

**Table 7.—The toxicity of 0.5 and 10.0 per cent poison in Volclay based on the time for 50 per cent kill of the confused flour beetle[1] and arranged in grades according to their toxicities.**

| Poison | Per Cent of Poison | | |
|---|---|---|---|
| | 0.5 | 10.0 Age I | 10.0 Age II |
| Rotenone | — | 1 | 1 |
| Phenylarsonic acid | — | 2 | 2 |
| m-Chlorophenylarsonic acid | — | 3 | 2 |
| DDT | — | 4 | 4 |
| Arsenious oxide | — | 4 | 9 |
| 2-Amino-1-naphthalenearsonic acid | 13 | 5 | 7 |
| 2-Nitro-1-naphthalenearsonic acid | 14 | 7 | 7 |
| m-Tolylarsonic acid | — | 8 | 8 |
| m-Nitrophenylarsonic acid | — | 8 | 9 |
| 2,4-Diaminophenylarsonic acid | — | 8 | — |
| 4-Amino-1-naphthalenearsonic acid | 14 | 8 | 7 |
| o-Aminophenylarsonic acid | — | 9 | 10 |
| 2,4-Dinitrophenylarsonic acid | — | 9 | — |
| Ethylarsonic acid | — | 9 | — |
| 1-Nitro-2-naphthalenearsonic acid | 15 | 9 | — |
| 8-Amino-1-naphthalenearsonic acid (Green) | 15 | 9 | — |
| 1-Amino-2-naphthalenearsonic acid | 14 | 9 | — |
| 2-Nitro-4-hydroxyphenylarsonic acid | — | 9 | — |
| 5,5′-Dihydroxy-2,2′-dichloroarsenobenzene monohydrate | — | 9 | — |
| p-Tolylarsonic acid | — | 10 | — |
| p-Chlorophenylarsonic acid | — | 10 | — |
| p-Nitrophenylarsonic acid | — | 10 | — |
| n-Propylarsonic acid | — | 10 | — |
| 4-Nitro-1-naphthalenearsonic acid | 17 | 10 | — |
| 8-Amino-2-naphthalenearsonic acid | 15 | 10 | — |
| 6-Amino-2-naphthalenearsonic acid | 14 | 10 | — |
| 3-Nitro-4-methylphenylarsonic acid | — | 10 | — |
| o-Chlorophenylarsineoxide | — | 10 | — |
| 2-Amino-4-hydroxyphenylarsonic acid monohydrate | — | 10 | — |
| o-Isoamyl-aminophenylarsonic acid | — | 10 | — |
| Lead arsenate | — | 11 | — |
| Basic lead arsenate | — | 11 | — |
| o-Chlorophenylarsonic acid | — | 11 | — |
| m-Aminophenylarsonic acid | — | 11 | 13 |
| Sodium p-hydroxyphenylarsonate | — | 11 | — |
| 6-Nitro-2-naphthalenearsonic acid | 15 | 11 | — |
| 5-Amino-1-naphthalenearsonic acid | 16 | 11 | — |
| 8-Amino-1-naphthalenearsonic acid (Dark green) | 16 | 11 | — |
| Diphenylarsinic acid | — | 11 | — |
| m-Acetylphenylarsonic acid | — | 11 | — |
| 4-Arsono-N-2-thiazolebenzenesulfonamide | — | 11 | — |
| 2-Nitro-diphenylamine-4-arsonic acid | — | 11 | — |
| 2-Chloro-5-aminophenylarsonic acid | — | 11 | — |
| Sodium fluoride | — | 12 | — |
| o-Tolylarsonic acid | — | 12 | — |
| p-Aminophenylarsonic acid | — | 12 | — |
| p-Benzarsonic acid | — | 12 | — |
| p-Hydroxyphenylarsonic acid | — | 12 | — |
| 5-Nitro-1-naphthalenearsonic acid | — | 12 | — |

[1] Adult beetles 157 to 171 days old were used in the 2.0 per cent poisons. Two age groups of beetles were used in the 10.0 per cent poisons. Age I group consisted of adult beetles 130 to 137 days old and Age II group of adult beetles 168 to 175 days old.

Table 7.—(Continued)

| Poison | Per Cent of Poison | | |
|---|---|---|---|
| | 0.5 | 10.0 Age I | 10.0 Age II |
| 8-Nitro-2-naphthalenearsonic acid | — | 12 | — |
| Di-(3-nitrophenyl)-arsinic acid | — | 12 | — |
| Triphenylarsine | — | 12 | — |
| p-Dimethylaminoazophenylarsonic acid | — | 12 | — |
| o-Nitrophenylarsonic acid | — | 13 | — |
| 8-Nitro-1-naphthalenearsonic acid | — | 13 | — |
| Check (Volclay only) | 17 | 11 | 13 |

made to compare them at different concentrations for the following reasons: 1. The resistance of the beetles to these poisons differed considerably even when the age range differed only slightly. 2. The action of some of the poisons varied so greatly that their orders of toxicity were reversed when beetles of different ages were used, as in the case of m-chlorophenylarsonic acid and n-propylarsonic acid at 0.5 per cent concentration in flour. On the other hand, the use of more than one concentration may give the following information: 1. The repellent action of a poison when applied as a stomach insecticide. 2. The correct concentration for effective control. 3. The reaction speed of a poison. 4. A suitable concentration for comparing the relative toxicities of the poisons.

From the statistical analyses (Table 3), it is shown clearly that the variation due to replication is generally insignificant except in the cases of 0.5 and 10.0 per cent concentration of poison in sand. These exceptions may be attributed to the fact that a slight difference in the time of paralyzing the beetles may greatly affect the time of death because the presence of elytra may prevent or slow down the entrance of poison into the bodies of insects after they have turned over on their backs. The variation due to kinds of poisons and to the age of the insects is always highly significant. The variation due to the interaction between the different kinds of poisons and different age ranges of insects is usually highly significant with the exception of a 10 per cent concentration in flour. This exception probably can be explained by the fact that at this high concentration of the poisons, high toxicity would overcome the smaller but significant differences ascribed to the interaction between the different kinds of poisons and different age ranges of the insect. It may also explain why many highly toxic poisons could not be differentiated from each other with respect to their toxicity at high concentrations.

The data were mainly arranged according to the toxicity of the poisons. Only those poisons showing promise were included in tables 5, 6, 7. According to this arrangement, the poisons which fall into any one group definitely do not show significant differences in their toxic properties. The poisons in the adjoining grade may or may not show significant differences from those of the first group. The poisons that differ by more than one grade have significant differences in toxicity.

The data reveal that some organic arsenicals, such as m-chlorophenylarsonic acid and phenylarsonic acid, can be compared with the best insecticides used at the present time and are far superior to acid lead arsenate, sodium fluoride and to basic lead arsenate. Some of the amino- and nitro-naphthalenearsonic acids, especially 2-amino-1-naphthalenearsonic acid, have very good prospects as superior insecticides for these naphthalenearsonic acids usually are quite insoluble in water. Furthermore, it was pointed out earlier that inorganic arsenic compounds are not good poisons for the confused flour beetle. It is very probable that the organic arsonic acids may be even more effective when they are applied to some arsenic susceptible insects. The practical use of these poisons needs further study.

Richardson *et al.* (1923) pointed out that in the present state of our knowledge of insecticides, it is doubtful whether one may safely draw any far-reaching conclusions as to the relationship between the chemical structure of compounds and their toxicity. Unfortunately it is true even at the present time. A change of the structure of a compound can alter its chemical properties as well as its physical properties, and some of these changes may enhance the toxicity of a compound while others may decrease it. The apparent toxicity of a compound can also be varied by the method of testing, by the insect chosen for testing, and by many other factors. Furthermore, there are many instances when one poison is more toxic

than another at a low concentration while the reverse is true at a higher concentration. Examples of this relation are afforded by the comparative toxicities of o-amino-phenylarsonic acid and m-amino-phenylarsonic acid, and DDT and rotenone. This variation may be due to the following factors: 1. The speeds of poisoning of these two compounds are different. 2. The repellent actions of these two compounds are different. 3. The efficiencies of these two compounds as stomach and contact poisons are different. In comparing toxicities, the figures at the low concentration were used and the following conclusions are drawn accordingly (Table 2).

1. The introduction of a methyl group into phenylarsonic acid causes a definite decrease in toxicity. The toxicity of the resulting compounds varies with the entering position of the methyl group in the following order:

(1) As stomach and contact poisons in flour: meta>para>ortho
(2) As contact insecticides in sand: meta>ortho>para
(3) As contact insecticides in *Volclay:* meta>para>ortho

The introduction of a nitro group into the m-position of p-tolylarsonic acid seems to increase its value as a stomach poison and decrease its value as a contact poison.

2. The introduction of a chloride group into phenylarsonic acid causes a definite decrease in toxicity with the exception of meta-substituted compounds. The toxicities of the resulting mono-chloroderivatives, with the m-substituted compound far more toxic than the o- and p- substituted compounds, can be arranged as follows:

(1) As stomach and contact poisons in flour: meta>ortho>para
(2) As contact insecticides in sand: meta>ortho>para
(3) As contact insecticides in *Volclay:* meta>ortho>para

The introduction of a hydroxy group into the ortho position of o-chlorophenylarsonic acid increases the toxicity. On the other hand, the similar introduction of an amino group decreases the toxicity.

3. The introduction of a nitro group into phenylarsonic acid causes a definite decrease in toxicity. The toxicities of the resulting compounds vary with the entering position of the nitro group as follows:

(1) As stomach and contact poisons in flour: meta>para>ortho
(2) As contact insecticides in sand: ortho>meta>para
(3) As contact insecticides in *Volclay:* meta>para>ortho

The introduction of a nitro or hydroxyl group in the para position of o-nitrophenylarsonic acid generally increases the toxicity except in the cases where these are mixed with sand in 0.5 per cent concentration. The introduction of the nitro group is more effective than the introduction of the hydroxyl group in increasing toxicity. The introduction of a methyl group to the para position of m-nitrophenylarsonic acid decreases in toxicity in all cases tested.

4. The introduction of an amino group into phenylarsonic acid decreases the toxicity. The toxicities of the resulting compounds can be arranged as follows:

(1) As stomach and contact poisons in flour: ortho>meta>para
(2) As contact insecticides in sand: meta>ortho>para
(3) As contact insecticides in *Volclay:* ortho>meta>para

The introduction of another amino group in the para position of o-aminophenylarsonic acid greatly enhances its toxicity as a stomach poison, and slightly as a contact poison in *Volclay*, but reduces its value as a contact poison in sand. The replacement of one of the amino hydrogens in o-aminophenylarsonic acid with the isoamyl radical increases its stomach poisoning effect but decreases its contact poisoning effect. The introduction of a hydroxyl group in the para position of o-aminophenylarsonic acid does the same thing. The introduction of a chlorine atom in position six of 3-aminophenylarsonic acid increases its value as a stomach poison and decreases its value as a contact poison in sand.

5. All of the o-substituted phenylarsonic acids tested are less effective than the parent compound. In general, they are only slightly effective against this beetle and behave neither as a good stomach poison nor as a valuable contact poison. The relative toxicity of these compounds is indicated in these series:

(1) As stomach and contact poisons in flour: chloro>amino>methyl>nitro
(2) As contact insecticides in sand: amino>nitro>methyl>chloro

(3) As contact insecticides in *Volclay:*
amino>chloro>methyl>nitro

6. All of the p-substituted phenylarsonic acids tested are less effective than the original compound. The toxicities of these compounds present this order of activity:

(1) As stomach and contact poisons:
chloro=nitro>methyl>carboxy>amino>hydroxy
(2) As contact poisons in sand:
chloro=amino=methyl>nitro>hydroxy>carboxy
(3) As contact poisons in *Volclay:*
chloro=amino=methyl

The other three compounds in *Volclay* do not have any effect as contact poisons. The formation of sodium salt of the p-hydroxyphenylarsonic acid greatly increases its stomach poisoning action.

7. The m-substituted phenylarsonic acids are usually more toxic than their p- and o-isomers. With the exception of m-chlorophenylarsonic acid, the m-substituted phenylarsonic acids are less effective than the original compound. The toxicity of the m-substituted phenylarsonic acids can be arranged in this order of effectiveness:

(1) As stomach and contact poisons:
chloro>nitro>methyl>acetyl>amino
(2) As contact poisons in sand:
chloro=amino=acetyl>nitro
chloro>methyl>nitro
(3) As contact poisons in *Volclay:*
chloro>methyl=nitro>amino=acetyl

8. There are definite differences between the toxicity of the arsonic acids and their corresponding arsine oxides but no general rule can be formulated. With some derivatives the arsonic acid is more toxic than the corresponding arsine oxide and in others the situation is reversed. It is worth while to mention that the arsine oxides are usually more insoluble in water than their corresponding arsonic acids and thus may be more useful as insecticides.

9. There is no striking difference between the toxicities of the arsonic acids and their corresponding arsenobenzenes, although the arsenobenzenes contain more arsenic than do their corresponding arsonic acids.

10. In the 1- and 2-naphthalenearsonic acids, there are very many positions which can be substituted with different radicals. Only the nitro and amino groups are included in this study. These substituted compounds differ in toxicity because of the difference in the position of the arsono, the nitro and amino groups. It is clearly shown in the following that, with the introduction of an amino or nitro group into the 1- or 2-naphthalenearsonic acids, the toxicities of the resulting compounds aer generally more marked where the introduced group enters the ring which contains the arsono group than if the introduced group enters the other ring.

(a) The toxicities of the nitronaphthalenearsonic acids can be graded as follows:

(1) As stomach and contact poisons in flour:
2-nitro-1-arsono=1-nitro-2-arsono=4-nitro-1-arsono>8-nitro-2-arsono>6-nitro-2-arsono=5-nitro-1-arsono>8-nitro-1-arsono
(2) As contact poisons in sand:
2-nitro-1-arsono>1-nitro-2-arsono=4-nitro-1-arsono>8-nitro-1-arsono=6-nitro-2-arsono>5-nitro-1-arsono=8-nitro-2-arsono
(3) As contact poisons in *Volclay:*

No appreciable poisoning effect from these poisons was observed because *Volclay* itself behaves as a contact insecticide. Only 2-nitro-1-naphthalenearsonic acid showed some promise as a contact insecticide.

(b) The relative toxicities of the aminonaphthalenearsonic acids are indicated in the following series:

(1) As stomach and contact poisons in flour:
2-amino-1-arsono>4-amino-1-arsono>1-amino-2-arsono>8-amino-1-arsono(green)>6-amino-2-arsono>5-amino-1-arsono=8-amino-2-arsono>8-amino-1-arsono (dark green)
(2) As contact poisons in sand:

The 2-amino-1-naphthalenearsonic acid and 4-amino-1-naphthalenearsonic acid are definitely superior in toxicity to the rest of the amino-naphthalenearsonic acids which do not differ to any great extent.

(3) As contact poisons in *Volclay:*

No appreciable poisoning effect with these compounds was observed because *Volclay* itself behaves as a contact insecticide.

11. There are a few organic arsonic acids —such as p-2′-hydroxypropoxy-3-nitrophenylarsonic acid, diphenylether-o, o′-diarsonic acid and 3,4-dimethoxy-5-acetylphenylarsonic acid—which do not show any noticeable toxicity to the beetles even at 10 per cent concentration in flour.

SUMMARY.—Sixty-one organic arsenic compounds have been tested as both stomach and contact poisons against the confused flour beetle. The effective poisons among them were graded according

to their lethal properties as measured by the time required for a 50 per cent kill. It was found that m-chlorophenylarsonic acid, phenylarsonic acid, 2-amino-1-naphthalenearsonic acid and a few others showed very promising insecticidal properties.

The relationship between the structure and toxicity of these arsenicals has been formulated tentatively. In the phenylarsonic acid series, the m-substituted compounds generally were more effective than their corresponding *ortho-* and *para* isomers. In the nitro- and aminonaphthalenearsonic acid series, the compounds usually were more effective when the amino or the nitro group was on the ring containing the arsono group.

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ERRATUM: JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 40 (5), October 1947; Page 649; Walter M. Kulash, "Benzene Hexachloride and Chlordane to Control the Boll Weevil. On this page lines 2 to 9, column 2, below the table, should read as follows: "At 48 hours after treatment there was a significant difference in the number of weevils knocked down and killed at the 1.0, 0.5 and 0.2 per cent concentration. The 0.2 per cent concentration, though not significantly different from the 0.1 per cent concentration.

# Tests of Insecticides for Control of Grasshoppers[1]

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Over a period of years the common method of controlling grasshoppers has been the use of poisoned baits. Even with persistent baiting this method has not satisfactorily protected crops from this pest in Central Texas. Especially in the past 2 years, considerable damage has occurred as a result of grasshoppers dispersing from weed fields and pastures into cultivated crops. Baiting in such fields did reduce the numbers of grasshoppers, but not enough to prevent injury to bordering crops. Arsenicals and other old insecticides have proven ineffective in either dust or spray form.

Tests conducted by Kearns *et al.* (1945) divulged that chlordane proved to be toxic to grasshoppers. Brett & Rhoades (1946) reported the toxicity of benzene hexachloride to these pests. Hinman & Cowan (1947) and Weinman *et al.* (1947) summarized the results of field tests denoting the comparative effectiveness of benzene hexachloride, toxaphene and chlordane when used as sprays and dusts for grasshopper control. After critical examination of the action of these insecticides, Weinman & Decker (1947) came to the conclusion that these materials represented a combination of both stomach and contact poisons. The action of benzene hexachloride appeared to be chiefly by contact, while chlordane and *Toxaphene*[2] acted principally as a stomach poison.

The laboratory and field tests herein reported were conducted near College Station, Texas, during the spring of 1947 in an effort to aid planters in developing a more effective and economical control of grasshoppers in this area. Mixed populations of grasshoppers were found to occur, but the majority of them were *Melanoplus differentialis* (Thos.). Hatching was thought to be complete by May 5 at which time the first field test was started. Grasshopper nymphs were used in all tests before they had reached the fifth instar. Untreated cages of grasshoppers or plats were used in practically all experiments and the percentage mortalities were calculated by the use of Abbott's formula. In one or two instances percentage reductions are given, in which cases no checks were used.

Laboratory Tests.—These tests were conducted for the purpose of comparing the toxicity both as a contact and as a stomach poison of benzene hexachloride, chlordane, *Toxaphene* and aryl alkyl thionophosphate to grasshopper nymphs. In experiment 1, cotton plants were dusted under a cylinder with a pre-determined dose of each insecticide. A 27-inch screen cage was placed over each plant. Approximately 25 field-collected nymphs were released in each cage within an hour after the dust had been applied to the plants. In experiment 2, the nymphs were dusted and placed in cages containing clean cotton plants to compare the contact action of these insecticides. Results of these tests are shown in tables 1 and 2.

On experiment 1, in which only the plants were dusted, chlordane proved more toxic than either benzene hexachloride, benzene hexachloride-DDT mixture, *Toxaphene* or aryl alkyl thionophosphate. Although the grasshopper nymphs came in contact with the materials on the plants, it was assumed that the results of these tests were principally the action of stomach poisons.

In experiment 2, in which only the grasshopper nymphs themselves were dusted, benzene hexachloride proved to be the most effective material used. Chlordane and aryl alkyl thionophosphate were more toxic than *Toxaphene*. These tests show the effectiveness of the materials as a contact poison only.

Field Experiments.—In these tests located in both weed fields and alfalfa, quarter acre plats were used. The baits were mixed with water just before they were applied. All dusts were applied with rotary hand guns exclusively with the exception of one instance in which an airplane was used. Both baits and dust applications were made in the morning just after dawn. The sprays were applied in the afternoon at a pressure of 200 pounds using a small power machine.

The results of these tests were evaluated by sweeping with an insect net the

[1] Technical contribution No. 1048 Texas Agricultural Experiment Station. H. A. Dean and Read Wipprecht assisted in making the field records.

[2] A chlorinated camphene.

**Table 1.—Mortality of grasshopper nymphs following dust applications to caged cotton plants.**

| Treatment | Concentration of Dust Mixture, Per Cent | Dosage of Dust Mixture, Pounds per Acre | Number of Insects | Number of Cages | Per Cent Mortality After— 1 day | 2 days | 3 days | 4 days | Average |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Exp. 1 | | | | | |
| Chlordane | 10 | 10 | 175 | 7 | 27.6 | 46.5 | 44.5 | 44.5 | 40.1 |
| Benzene Hexachloride | 3[1] | 10 | 168 | 7 | 26.0 | 40.5 | 38.8 | 38.1 | 35.8 |
| Benzene Hexachloride-DDT | 3[1]–5[2] | 10 | 90 | 4 | 22.5 | 25.0 | 29.3 | 32.6 | 27.4 |
| *Toxaphene* | 10 | 10 | 94 | 4 | 20.5 | 38.6 | 45.0 | 40.0 | 36.0 |
| Aryl alkyl Thionophosphate | 1 | 16 | 99 | 4 | 14.0 | 24.5 | 26.2 | 25.6 | 22.6 |

[1] Gamma isomer.
[2] Per cent DDT.

treated and untreated plats before and after treatment.

In experiment 3, the initial infestation of grasshopper nymphs averaged 77 per 50 sweeps and the first application of baits was made at the rate of 10 pounds per acre. The second application was applied at the rate of 20 pounds. The results of these tests are shown in table 3. Of the baits used, *Toxaphene* emulsion and chlordane proved more effective. *Toxaphene* dust or spray and chlordane spray were also effective. *Toxaphene* dust applied at the rate of 1.8 pounds chlorinated camphene per acre was approximately as effective as chlordane spray when applied at 2 pounds chlordane per acre.

In experiment 4, the initial infestation of grasshopper nymphs averaged 104 per 50 sweeps. *Toxaphene*, chlordane and benzene hexachloride dusts and dust mixtures were used in different concentrations to determine their effectiveness. The results are shown in table 4. *Toxaphene* dust of a low concentration applied by airplane gave better control than similar dust applied with hand guns. The applications with hand guns were made under poor weather conditions. In other experiments it has been observed that some of these insecticides proved much more effective applied when the air was calm and dew present.

**Table 2.—Mortality of grasshoppers following dust applications to the nymphs and immediately placed on clean caged cotton plants.**

| Treatment | Concentration of Dust Mixture- Per Cent | Dosage of Dust Mixture Pounds per Acre | Number Insects | Reduction in 48 Hours, Per Cent |
|---|---|---|---|---|
| | | Exp. 2 | | |
| Benzene hexachloride | 3[1] | 10 | 99 | 96.0 |
| Chlordane | 10 | 10 | 94 | 69.1 |
| *Toxaphene* | 15 | 10 | 99 | 34.3 |
| Aryl alkyl Thionophosphate | 1 | 16 | 100 | 65.0 |

[1] Gamma isomer.

In experiment 5, the initial infestation averaged 364 grasshopper nymphs per 50 sweeps. These quarter-acre plats were located in the edge of a large alfalfa field. On the day the second application of dusts was made, the field of alfalfa was mowed, leaving each plat equally exposed to the migration of nymphs from the cut alfalfa. The day after the alfalfa was cut the nymph population in the check plat increased about 500 per cent. This increase in grasshopper population shows the critical test to which these insecticides were subjected. *Toxaphene* dust applied at an average rate of 1.3 pounds chlorinated camphene per acre, chlordane at 1.1 pounds per acre and benzene hexachloride at 0.3 pound gamma isomer per acre gave effective control. The *Toxaphene*-calcium arsenate mixture was also effective, but little is known regarding the possible breakdown of *Toxaphene* when mixed with a highly alkaline material. The effective-

**Table 3.—Mortality of grasshopper nymphs following bait, spray and dust applications in weeds.**

| Treatments | Per Cent Mortality After 1st Application | | | | Per Cent Mortality After 2nd Application | | | Average |
|---|---|---|---|---|---|---|---|---|
| | 1 Day | 2 Days | 5 Days | 7 Days | 1 Day | 4 Days | 6 Days | |
| 6 lbs. sodium fluosilicate 25 lbs. bran 75 lbs. sawdust | 22.8 | 56.0 | | 38.5 | 10.1 | 66.0 | 80.3 | 45.6 |
| 12 lbs. *Toxaphene*, 25% wettable chlorinated camphene 25 lbs. bran 75 lbs. sawdust | 21.0 | 20.1 | | 0 | 32.7 | 78.4 | 67.9 | 36.7 |
| 6 lbs. *Toxaphene* emulsion, 50% chlorinated camphene 25 lbs. bran 75 lbs. sawdust | 52.2 | 33.0 | | 46.0 | 84.3 | 86.2 | 74.6 | 62.7 |
| 6 lbs. benzine hexachloride wettable, 7.5% gamma isomer 25 lbs. bran 75 lbs. sawdust | 0.0 | 0.0 | | 24.9 | 60.2 | 83.3 | 71.1 | 39.9 |
| 6 lbs. chlordane wettable 50% chlordane 25 lbs. bran 75 lbs. sawdust | 4.9 | 9.1 | | 73.1 | 96.9 | 96.7 | 91.3 | 62.0 |
| *Toxaphene* dust, 20% Chlorinated camphene (9 lbs. per acre) | 96.1 | 98.5 | | 80.3 | | | | 91.6 |
| *Toxaphene* spray, 1 lb. chlorinated camphene per acre | | 78.6 | 81.3 | 69.3 | | | | 76.4 |
| Chlordane spray, 2 lbs. chlordane per acre | | 97.7 | 87.9 | 95.2 | | | | 93.6 |

**Table 4.—Mortality of grasshopper nymphs following dust applications in weeds.**

| Treatment | Pounds per Acre | Per Cent Mortality Following Application | | | |
|---|---|---|---|---|---|
| | | 1 Day | 5 Days | 8 Days | Average |
| *Toxaphene*-inert (5% chlorinated camphene) | 10.4 | 76.8 | 68.0 | 58.4 | 67.7 |
| *Toxaphene*-inert (10% chlorinated camphene) | 14.0 | 24.8 | 79.5 | 0.0 | 34.8 |
| *Toxaphene*-inert (15% chlorinated camphene) | 9.2 | 50.8 | 84.1 | 49.9 | 61.6 |
| *Toxaphene*-inert (20% chlorinated camphene) | 30.8 | 95.1 | 100.0 | 52.1 | 82.4 |
| Benzene hexachloride-inert (3% gamma isomer) | 11.2 | 71.5 | 70.7 | 56.2 | 66.1 |
| Benzene hexachloride-DDT-inert (3% gamma isomer, 5% DDT) | 20.0 | 100.0 | 77.4 | 87.1 | 88.2 |
| Chlordane-inert (5% chlordane) | 11.6 | 54.1 | 64.7 | 24.2 | 47.7 |
| Calcium arsenate-*Toxaphene* 75% cal. ars., 10% c. camphene | 12.0 | 91.4 | 68.3 | 70.7 | 76.8 |
| *Toxaphene*-inert[1] 10% chlorinated camphene | 10.0 | | 91.4 | 83.4 | 87.4 |

[1] Applied by airplane.

ness of these materials under field conditions indicates both contact and stomach poison effect.

In this area, considerable acreages of weed fields, fence rows, edges of alfalfa and cotton fields were treated with *Toxaphene* and benzene hexachloride dusts using both airplane and ground machinery. These dusts were effective and prevented damage to cultivated crops. When the grasshopper populations were high, from 1.5 to 2 pounds of *Toxaphene* per acre or

**Table 5.—Mortality of grasshopper nymphs following dust applications in alfalfa.**

| Treatments | Average Pounds per Acre | Per Cent Mortality | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | After 1st Application[1] | | After 2nd Application[1] | | | After 3rd Application | | | |
| | | 5 Days | 6 Days | 1 Day | 2 Days | 4 Days | 1 Day | 3 Days | 4 Days | Average |
| *Toxaphene*-inert (10% chlorinated camphene) | 12.8 | 82.7 | 90.9 | 94.2 | 75.2 | 74.8 | 99.0 | 97.1 | 95.5 | 88.7 |
| *Toxaphene*-calcium arsenate (10% chlorinated camphene, 75% calcium arsenate) | 9.3 | 76.9 | 84.8 | 97.8 | 97.6 | 93.1 | 98.9 | 99.0 | 98.2 | 93.3 |
| Chlordane-inert (5% chlordane) | 22.4 | 79.8 | 83.2 | 91.8 | 88.1 | 86.7 | 98.0 | 93.5 | 97.6 | 89.8 |
| Benzene hexachloride-inert (3% gamma isomer) | 10.4 | 61.9 | 74.8 | 91.1 | 81.0 | 71.9 | 99.3 | 97.1 | 97.4 | 84.3 |

[1] The first and second applications were washed off by rains within 30 hours after they were applied.

at least 0.3 pound of gamma isomer per acre were necessary to give adequate control. The best results were obtained when the materials were applied during favorable weather conditions. The effectiveness of benzene hexachloride dust was greatly reduced by wind drift.

SUMMARY.—The action of *Toxaphene*, chlordane, benzene hexachloride and aryl alkyl thionophosphate represented a combination of stomach-poison and contact insecticidal effect. Apparently benzene hexachloride acted more as a contact than as a stomach poison. The aryl alkyl thionophosphate was used only at the low concentration of 1 per cent, and was not as effective at this concentration as the other materials. Sufficient quantities of this material were not available for field tests.

Results of field tests indicate that chlordane, *Toxaphene* and benzene hexachloride are effective against grasshopper nymphs. *Toxaphene* and chlordane applied as either a dust or a spray at from 1.5 to 2 pounds of chlorinated camphene or chlordane were effective against large numbers of grasshoppers. Benzene hexachloride dust mixture applied at 0.3 pound gamma isomer per acre was also effective against large numbers of grasshopper nymphs. This material should be applied under favorable dusting conditions to obtain the best results and conserve materials.

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# Insecticides to Control Tobacco Thrips and Potato Leafhopper on Peanuts[1]

F. W. Poos, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*, and J. M. Grayson, and E. T. Batten, *Virginia Agricultural Experiment Station*

Two important insect pests of growing peanuts in southeastern Virginia are the tobacco thrips, *Frankliniella fusca* (Hinds), and the potato leafhopper, *Empoasca fabae* (Harr.). The tobacco thrips attacks the developing leaflets of young peanut plants soon after they appear above ground. Slight to moderate injury causes the leaflets to be scarred or misshapen, and severe injury turns all the terminal buds of seedling plants as black as if they had been burned. The first evidence of leafhopper injury is a yellowing on the tips of the leaflets. If the infestation is severe this yellowing spreads over the entire leaflets, and the whole plant becomes dwarfed. The purpose of this paper is to present results of tests conducted at Holland, Virginia, during 1945 and 1946 for the control of the tobacco thrips and the potato leafhopper, and at Beltsville, Maryland, for the control of the tobacco thrips.

Thrips Injury.—Watson (1922) was apparently the first to notice thrips injury to peanuts when he reported widespread injury to very young peanut plants in Florida during the spring of 1919 in work on the Florida flower thrips, *Frankliniella bispinosa* Morgan. In 1941 *F. fusca* (Hinds) and *F. tritici* (Fitch) were reported (Poos 1941 and Shear & Miller 1941) in collections of thrips made from peanuts in Georgia, South Carolina, and Virginia. Poos (1941) reported that immature thrips collected from injured peanut plants and reared to adults were all identified as *F. fusca* (Hinds), which would indicate that *F. fusca* breeds in the peanut leaflets but *F. tritici* (Fitch) does not. *Frankliniella tritici* was found mainly in the blossoms. More complete studies[2] made later confirmed these results.

Prior to 1944 attempts to control the tobacco thrips on seedlings peanuts with weekly or even more frequent applications of the insecticidal formulations available at that time were unsuccessful. Results of tests made in 1944 at Beltsville, Maryland, (Poos 1945b) with three different formulations containing DDT indicated that this material effectively controls the tobacco thrips on seedling peanuts and that yields, based on total green weight of vines and pods at digging time, were thereby increased significantly. During 1945 and 1946 studies were continued at Beltsville and also at Holland to determine the most effective insecticidal formulations for controlling this insect on seedling peanuts and the best time for and the least number of applications required for this purpose.

*Tests at Beltsville Research Center.*—The methods employed and the locations of tests during 1945 and 1946 for the control of the tobacco thrips at Beltsville were similar to those used in 1944 and previously described (Poos 1945b), except that in 1946 the 4 per cent DDT emulsion was applied with a knapsack sprayer, to which was attached a Monarch-type oil-burner nozzle. It was not feasible to measure the amount of material applied to each plot.

The information relative to the two experiments conducted during 1945 is shown in table 1. In 1945 the first treatment was not applied until June 18, whereas in 1944 injury to seedling peanuts from the tobacco thrips appeared earlier and was more severe, and the first treatments were applied on June 7, Although thrips injury to the plants was not very severe in 1945, in experiment 1 the yields from the treated plots averaged from 21 to 36 per cent greater than those from the untreated areas. These differences are significant in all cases. Although some of the same treatments were applied in experiment 2, no significant increases in yield resulted, probably because the part of the field used for experiment 2 was lower, more fertile, and perhaps more moist than the part used for experiment 1. Consequently, the untreated seedling peanut plants in experiment 2 recovered from

[1] Acknowledgment is made to the Division of Insecticide Investigations, U. S. Bureau of Entomology and Plant Quarantine, for analyses of peanut hay for DDT residues reported in this paper; also to F. M. Wadley, formerly statistical consultant of the same Bureau, for guidance in the application of statistical methods.

[2] Specific identifications were all made by J. C. Crawford of the Bureau of Entomology and Plant Quarantine.

thrips injury more rapidly than those in experiment 1. Samples taken from these plots at digging time in October showed DDT residues ranging from 0.4 to 6.4 p.p.m. These residues were lower than expected because applications of a dust containing 2 per cent of DDT in pyrophyllite were made on August 2 and 23 for control

tained from the treated plots in experiment 1 than from those in experiment 2. The explanation is perhaps the same as that stated in the preceding paragraph since, again, experiment 1 was conducted on less fertile soil. However, the differences failed to reach significance at the 5 per cent level in either experiment.

**Table 1.—Yields of peanuts (vines and pods) from plots treated with DDT insecticides for control of the tobacco thrips. Beltsville, Maryland, 1945. (5 replications.)**

| TREATMENT | DATES OF APPLICATION | AVERAGE TOTAL GREEN WEIGHT | AVERAGE INCREASE IN YIELD OVER CHECK |
|---|---|---|---|
| | | *Pounds* | *Per Cent* |
| Experiment 1 | | | |
| Untreated check | None | 44.35 | |
| Dust, DDT 2% in pyrophyllite | June 18, 23, 30, July 7 | 57.70 | 30.1 |
| | June 18, 23, July 4 | 60.60 | 36.6 |
| | June 23, July 7 | 59.05 | 33.1 |
| Emulsion, DDT 10% in pyrophyllite 9 oz., sodium oleylsulfate with synthetic-resin sticker 1½ teaspoonfuls, water 1 gal. | June 23, July 7 | 59.55 | 34.2 |
| Emulsion, DDT (technical) ¼ lb., xylene 10 fluid oz., Igepal CA[1] ½ fluid dram, water to make 1 gal., 1 part emulsion to 32 parts water | June 23, July 7 | 53.90 | 21.5 |
| Difference required for significance at 5% level | | 7.22 | |
| Experiment 2 | | | |
| Untreated check | None | 64.30 | — |
| Aerosol,[2] DDT 5%, cyclohexanone 5%, aromatic petroleum solvent 5%, acetone 35%, methyl chloride 50% | June 18, 23, July 3 | 73.35 | 14.07 |
| Dust, DDT 2% in pyrophyllite | June 18, 23, July 4 | 64.40 | 0.15 |
| Emulsion, DDT 10% in pyrophyllite 9 oz., sodium oleylsulfate with synthetic-resin sticker 1½ teaspoonfuls, water 1 gal. | June 18, 23, July 3 | 65.65 | 2.09 |
| Emulsion, DDT ¼ lb., xylene 1 fluid oz., Igepal CA ½ fluid dram, water to make 1 gal. (about 6 gal. per acre) | June 18, 23, July 3 | 67.30 | 4.6 |
| 1 part emulsion to 32 parts water (about 100 gal. per acre) | June 18, 23, July 3 | 62.55 | −2.7 |

[1] Condensation product of ethylene oxide and an alkylated cresol.
[2] Formula 50 supplied by L. D. Goodhue.

of the potato leafhopper in addition to those shown in table 1.

In 1946 the peanut seed was planted about ten days later than usual because of unfavorable weather conditions, and only moderate thrips injury developed on the plants. The treatments applied for the control of the tobacco thrips and the results obtained are shown in table 2. Ryania powder and benzene hexachloride were tested in addition to some of the formulations previously tested in 1945. Ryania powder, at the 1 per cent concentration, did not appear to be effective against the tobacco thrips on seedling peanuts when applied by conventional knapsack sprayer. Benzene hexachloride, in each of the formulations used, seemed to lack the residual effect obtained with the atomized 4 per cent DDT emulsion, but the thrips control on the plots treated with this insecticide was good, and the increases in yield on them were as great as those from some of the DDT treatments. Again, larger increases in yield were ob-

The DDT residues on the samples collected from the various plots on October 8 (table 2) are not excessive when consideration is given to the fact that applications of a dust containing 2 per cent of DDT in pyrophyllite were made to all the plots, including previously untreated plots, on July 30 and August 8 to control the potato leafhopper. The amounts of DDT reported on the forage were much higher in 1946 than those from similar experiments conducted during 1945. Possibly the dosages were much heavier in 1946 than in 1945 and also much heavier than may eventually be found necessary to control the potato leafhopper. Because such heavy residues were found at harvest-time in 1946 after minimum effective rates of application, it may be necessary to substitute other insecticides for DDT in late-season applications to control the potato leafhopper on peanuts that have been treated previously with DDT to control the tobacco thrips.

*Tests at Holland, Virginia.*—Similar

**Table 2.—Yields of peanuts (vines and pods) from plots treated with various insecticides for control of the tobacco thrips. Beltsville, Maryland. 1946.**

| Treatment | Dates of Application | Average Total Green Weight | Average Increase in Yield Over Check | DDT Residue on Hay (p.p.m.)[1] |
|---|---|---|---|---|
| | | *Pounds* | *Per Cent* | |
| Experiment 1 (6 replications) | | | | |
| Untreated check | None | 46.3 | | 35.6 |
| Emulsion, DDT ½ lb., xylene 10 fluid oz., Igepal CA ½ fluid dram, water to make 1 gal. | June 21, July 3, 9 | 63.3 | 36.7 | 41.0 |
| Dust, DDT 2% in pyrophyllite | June 24, July 3, 8 | 61.1 | 31.9 | 19.2 |
| | June 24, July 3 | 55.8 | 20.0 | 75.6 |
| Dust, benzene hexachloride (1% of gamma isomer) | June 24, July 3, 8 | 55.5 | 20.5 | 13.2 |
| | June 24, July 3 | 57.3 | 23.7 | 10.4 |
| Experiment 2 (5 replications) | | | | |
| Untreated check | None | 43.0 | | |
| Aerosol,[3] 5% DDT, cyclohexanone 5%, Velsicol AR-60[2] 5%, acetone 35%, Freon-12[4] 50% | June 21, July 3, 9 | 52.0 | 20.9 | 9.8 |
| Emulsion, wettable DDT 50% 1½ oz., water 1 gal. | June 24, July 3, 9 | 48.4 | 12.5 | 4.2 |
| Emulsion, benzene hexachloride 50% (10% of gamma isomer) 1½ oz., water 1 gal. | June 24, July 3, 9 | 58.6 | 36.2 | 26.8 |
| Emulsion, 100% Ryania powder 1½ oz., water 1 gal. | June 24, July 3, 9 | 52.0 | 20.9 | 2.0 |

[1] Dust containing 2% of DDT in pyrophyllite applied to all plots for leafhopper control on July 30 and Aug. 8. Sample from untreated buffer rows at border of field showed no DDT residue.
[2] An aromatic petroleum fraction.
[3] Supplied by Floyd F. Smith.
[4] Dichlorodifluoromethane.

methods and plot arrangements were employed during 1945 and 1946 in the experiments conducted at Holland to control the tobacco thrips on seedling peanuts. The seed was planted on May 21, 1945, and May 10, 1946. In order to facilitate curing of the crop in the normal manner 0.027-acre plots were used. Each treatment with an untreated check was replicated five times. The methods of application were the same as those described for the experiments conducted at Beltsville, except that no aerosol was applied at Holland.

In 1945 the treatments consisted of one-, two-, and three-application schedules of a dust containing 2 per cent of DDT in pyrophyllite and a three-application schedule with each of two liquid formulations containing DDT. Yields of field-cured hay and peanuts were determined at harvest-time. The differences among the various treatments were not significant, as was expected since the amount of injury to both treated and untreated peanut plants from thrips was very light, and all of the plants rapidly recovered from the injury. One application of dusting sulfur was made to these plots during July and another during August for the control of the potato leafhopper and peanut leaf spot. The DDT residues found on samples of hay taken from the different plots on October 31 ranged from 18.0 to 72.6 p.p.m., ratios much higher than have been reported for any similar test.

The formulations tested in 1946 for the control of the tobacco thrips and the results obtained are shown in table 3. The 4 per cent DDT emulsion was atomized with a Monarch-type oil-burner nozzle attached to a knapsack sprayer and applied at a rate of approximately 3 pounds of DDT per acre-application. Data presented in table 3 clearly indicate that the atomized DDT emulsion gave highly significant control, since plants treated with this material showed an average of only 2.2 injured leaflets as compared with 41.8 injured leaflets on the untreated plants. The plots treated with 4 per cent DDT emulsion also gave an increase of 16.8 per cent in field-cured peanuts and 34 per cent in hay, as compared with the untreated plots. However, the increases in yield obtained in this experiment were not significant at the 5 per cent level. This may have been partly due to the fact that the tests at Holland during 1945 and 1946 were conducted on soil of higher fertility than the average used for growing peanuts in Virginia. Peanuts grown on such soils are apparently better able to withstand, and recover from, thrips injury than those grown on poorer soils. It probably was also partly due to the fact that thrips injury, even on untreated peanut seedlings in the locality where the experiments were conducted, was not as severe as it has been during many years. The fact that no residues of DDT were reported present on any of the samples of hay collected in November for analysis was noteworthy.

Further studies should be conducted to

**Table 3.—Effect of DDT and benzene hexachloride treatments for control of the tobacco thrips on seedling peanuts. Holland, Virginia. 1946.**

| Treatment | Dates of Application | Average Leaves per Plant[1] | Average Injured Leaflets per Plant[1] | Average Yield per Plot of Field-Cured | | Average Increase in Yield Over Check | |
|---|---|---|---|---|---|---|---|
| | | | | Nuts | Hay | Nuts | Hay |
| | | *Number* | *Number* | *Pounds* | *Pounds* | *Per Cent* | *Per Cent* |
| Untreated check | None | 23.4 | 41.8 | 40.4 | 88.2 | — | — |
| Emulsion, DDT 8 oz., xylene 10 fluid oz., Igepal 0.5 fluid dram, water to make 1 gal. | May 23, June 5, 18 | 22.8 | 2.2 | 47.2 | 118.2 | 16.8 | 34.0 |
| Dust, benzene hexachloride (1% of gamma isomer) | May 24, June 5, 18 | 21.7 | 15.6 | 39.6 | 96.8 | — | 9.7 |
| Dust, DDT 2% in pyrophyllite | May 24, June 5, 18 | 21.7 | 23.9 | 42.2 | 104.8 | 4.4 | 18.8 |
| | May 30, June 17 | 21.4 | 25.8 | 40.8 | 102.8 | 0.9 | 16.5 |
| | June 11 | 22.5 | 24.3 | 39.0 | 96.8 | — | 9.7 |
| Difference required for significance at 5% level[2] | | — | — | 6 | 32.2 | — | — |

[1] Based on a critical examination of 20 plants on each of the five replicates, June 19.
[2] Difference required for significance at 5% level 4.0, at 1% level 5.2.
[3] Acknowledgment is made to D. B. DeLury of the Virginia Agricultural Experiment Station for the statistical analysis of these data.

determine what losses in yield of field-cured nuts and peanut hay are caused by thrips when this crop is grown on soils of average, or less than average, fertility in the commerical peanut-growing area of Virginia. Further work is also needed to determine the minimum quantity and number of applications of DDT required to control the tobacco thrips effectively on peanuts, the best time to make them, and the most feasible formulations and methods to use.

POTATO LEAFHOPPER.—Results of preliminary tests conducted at Arlington, Virginia, in 1932 and 1933 on the control of the potato leafhopper on peanuts were reported in 1934 (Poos 1934). During 1934–1937 further tests were conducted in southeastern Virginia (Poos and Batten 1937, Batten and Poos 1938) which showed that significant increases in yield of field-cured peanuts and of peanut hay could be obtained by making applications of bordeaux mixture (4:4:50) or of sulfur dust (98 per cent through 325-mesh screen) to the peanut vines on about July 10, August 1, and August 20. This work, together with studies conducted by Miller (1942), led to the general practice in Virginia of applying sulfur dust to peanut foliage for the control of the potato leafhopper and peanut leaf spot. However, sulfur alone does not promptly reduce a high population of leafhoppers. With the advent of DDT, it seemed advisable to test the effectiveness of this material in combination with sulfur. Preliminary tests made in 1944 (Poos 1945a) showed DDT to be very toxic to the potato leaf hopper, and to have much greater residual effect than any material peviously tested. However, it was of no value for the control of the leaf spot on peanuts.

*Tests at Holland, Virginia.*—Experiments were conducted during 1945 at Holland for the purpose of comparing sulfur dusts containing 1 and 5 per cent of DDT, both as fused mixtures and as mechanical mixtures, with the standard 325-mesh sulfur-dust treatment for the control of the potato leafhopper and peanut leaf spot. Three applications of all materials were made. Each treated area consisted of an entire stack row of peanuts, 16 rows in width. The insecticides were applied with a mule-drawn four-row traction duster.

Although there was almost unprecedented rainfall during most of the growing season, the results of the tests indicated that the mechanical mixtures were as effective as the fused mixtures, also that sulfur containing 1 per cent of DDT was effective against the potato leafhopper, and therefore preferable to mixtures containing greater amount of DDT because of the lesser possibility of dangerous residues being left on the peanut hay. Analyses of samples collected in November showed 28.3 and 21.1 p.p.m. of DDT in the hay from the plots treated respectively with the fused and mechanical mixtures of sulfur containing 5 per cent of DDT on July 11 and 31 and August 18. Similar applications of sulfur dusts containing only 1 per cent of DDT showed only 0.22 p.p.m. of

DDT for the fused mixture and none for the mechanical mixture.

In 1946 three treatments with sulfur dusts containing DDT (all mechanical mixtures) were compared with three applications of 325-mesh dusting sulfur only. One treatment consisted of three applications of sulfur containing 1 per cent of DDT; another consisted of three applications of sulfur containing 2 per cent of DDT; and a third of two applications of sulfur containing 2 per cent of DDT followed by a third and final application of sulfur alone on August 21. Previous work has shown an application of sulfur dust about that date to be necessary in order to control peanut leaf spot. The potato leafhopper is seldom abundant enough on peanuts in Virginia as late as August 20 to require the application of an insecticide. DDT could thus be omitted from the late application if necessary in order to reduce the residue hazard on peanut hay.

Applications were made July 12 and 30 and August 21. Each treatment was replicated four times, and the test was designed to determine differences in effectiveness between treatments. Population counts of the potato leafhopper made on these plots were the lowest ever recorded in the Holland area, and the incidence of peanut leaf spot on the same plots was much less than usual. Thus, it was not surprising that the yields of field-cured nuts and of peanut hay obtained from the differently treated plots failed to show significant differences. However, the average reductions in potato leafhopper populations on the plots treated with DDT were 89 to 92 per cent as compared with only 68 per cent on the plots treated with sulfur alone.

Two hay samples were collected in November from each series of DDT-treated plots and analyzed for DDT residue. The maximum amount reported present in any sample was 4.5 p.p.m. The peanut hay fed to livestock normally contains fewer leaves (and therefore less DDT if the crop has been treated) after passing through the picker than were present on the samples collected prior to picking and submitted for analysis. Thus there would appear to be little liklihood of a residue problem, especially if no more than two applications (each of approximately 20 to 25 pounds per acre) of a sulfur dust containing only 2 per cent of DDT were applied to the peanut foliage prior to August 1.

The average yield obtained from all four of the treatments applied in each block in the 1946 tests and the yields of comparable adjacent untreated areas are given in table 2. The calculated differences required for significance are only approximate because of incomplete randomization. However, average increases of 22.9 per cent of field-cured peanuts and 10.3 per cent of hay from the treated areas are indicated.

**Table 4.—Comparison of average yields from treated and untreated areas maintained to study control of potato leafhopper and leaf spot on peanuts. Holland, Virginia. 1946.**

| Order of Areas | Field-cured Peanuts | Peanut Hay |
|---|---|---|
| | *Pounds* | *Pounds* |
| Untreated check | 77 | 203 |
| Block 1 | 103 | 213 |
| Block 2 | 114 | 208 |
| Untreated check | 93 | 210 |
| Block 3 | 121 | 231 |
| Block 4 | 132 | 225 |
| Untreated check | 117 | 183 |
| Difference required for significance at 5 per cent level | 31.6[1] | 23.7[1] |

[1] Approximate value because of incomplete randomization.

Summary and Conclusions.—Adequately replicated tests conducted on small plots at Beltsville, Maryland, and Holland, Virginia, during 1945 and 1946 with hand-operated equipment indicate that the tobacco thrips can be satisfactorily controlled on seedling peanuts with three, or probably fewer if properly timed, applications of certain formulations containing DDT. Best results were obtained with an emulsion containing 4 per cent of DDT applied by atomization at the rate of approximately 10 gallons per acre. Differences in yield at time of harvest between treated and untreated plots were significant where the tests were located on soils of low fertility, but these differences were not significant in similar plots located on more fertile soil. Plants grown in soil of low fertility appeared to be slower in recovering from the thrips injury than those growing in more fertile soil. Residues of DDT on hay samples collected at time of harvest in 1946 did not exceed 4.5 p.p.m., except in those cases where additional applications of a

dust containing 2 per cent of DDT in pyrophyllite were made during July and August to control the potato leafhopper.

Further studies should be conducted to determine the losses in yield of field-cured peanuts and peanut hay caused by the tobacco thrips, especially when the crop is grown on soils of average, or less than average, fertility in the commercial peanut-growing area of Virginia. More work is also needed to determine the minimum amount of DDT required to control this insect satisfactorily on peanuts, the best formulations to use, the best number and timing of applications, the most feasible method of application, and the residues to be expected from such treatments.

The results of field tests conducted during 1945 and 1946 at Holland, Virginia, for the control of the potato leafhopper on peanuts indicated that plots treated with various dust formulations containing DDT in combination with sulfur (in both fused and mechanical mixtures) failed to give significant increases in yields of field-cured peanuts and peanut hay, although some increase in yields from the treated plots was indicated. Satisfactory reductions in populations of the potato leafhopper were obtained with concentrations of DDT as low as 1 per cent in sulfur applied three times at approximately three-week intervals during July and August at the rate of 20 to 25 pounds per acre-application.

It seems probable that greater differences in yield would be obtained in more normal seasons and that a straight sulfur dust could be substituted for the third application. Unusually heavy rainfall occurred during the growing season of 1945, and in 1946 populations of the potato leafhopper were the lowest ever recorded in the Holland area. The highest amount of DDT reported on hay samples collected at time of harvest was 28.3 p.p.m. and resulted from three applications of a dust made from a fused mixture containing 5 per cent of DDT in sulfur. Residues at harvest-time on plants treated with three applications of sulfur mixtures containing 1 per cent and 2 per cent of DDT were not in excess of 4.5 p.p.m. Although these results are encouraging from the standpoint of the residue hazard on peanut hay, more tests are needed before DDT can be recommended for use on peanut forage that will be fed to livestock.

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# Piperonyl Butoxide with Pyrethrins in Wettable Powders to Control Certain Agricultural and Household Insects*

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The effectiveness of pyrethrum, particularly concentrated extracts containing the active principles, in sprays and dusts has been known for years. Despite the fact that of all the currently available insecticides pyrethrum, on a unit-weight basis is the most toxic to insects and at the same time the least toxic to warm-blooded animals, its utilization has been necessarily restricted by its relatively high cost. Efforts therefore have been made to develop synergists or activators which would permit the use of pyrethrum at an economical cost, but in most cases these "extenders" had a high degree of specificity which would not permit their use against a wide range of species of insects.

The linking by Haller and co-workers (1942) of the increased effectiveness of a methylene-dioxy-phenyl group contained in sesamin to the discovery by Eagleson (1940) that the addition of sesame oil to pyrethrum extracts increased their effectiveness against houseflies was a promising approach. Hedenburg (1946) had independently shown that certain compounds containing the methylene-dioxy-phenyl group were effective as insecticides, and from this research a technical product has been developed that has found prompt commercial acceptance under the name piperonyl cyclohexenone.[1] An intensified search for a product of increased activity and of complete miscibility with *Freon* and with petroleum hydrocarbons led to the synthesis by Wachs (1947) of (3,4-methylene-dioxy-6-propylbenzyl)(butyl) diethylene glycol ether, the technical grade of which is widely used commercially under the name of piperonyl butoxide.

Piperonyl butoxide has been found by Sarles (1947) to be free from all normal hazards of toxicity to warm-blooded animals. In combination with pyrethrins, it was no more toxic to laboratory animals than the diluent or oil used in making the solutions.

Dove (1947) has shown that piperonyl butoxide used alone in sprays and dusts was an effective insecticide without pyrethrins. Brannon (1947) has reported that a practicable concentration of piperonyl cyclonene alone in dusts gave significant control of the Mexican bean beetle. Brannon (1947) has reported that both piperonyl cyclonene and piperonyl butoxide are synergistic with rotenone. Apparently therefore the general classification of these compounds as activators or synergists for pyrethrum is not fully adequate, and while a new classification for these compounds is not proposed in this paper it should be borne in mind that they exhibit independent as well as synergistic activity.

Since piperonyl butoxide had given excellent results in petroleum oil sprays, liquefied-gas aerosols, and powders or dusts against the usual household insects and certain agricultural insects (Dove 1947), it was employed in wettable or water-dispersible powders in the study summarized in this paper. Wettable powders are most frequently used for application of surface or residual sprays. This study was designed therefore to determine the length of time over which one application of a wettable powder containing piperonyl butoxide and pyrethrins would remain effective.

Preparation of Wettable Powders.—In preparing the wettable powders used in these tests a mixture of piperonyl butoxide and pyrethrum extract was impregnated on the powdered carrier in a mixer. While mixing was continued, the powdered wetting and dispersing agents were added and the powder finally milled in a hammer mill. Diatomaceous earth (Celite 209) was used as the carrier in most cases for powders in which the active ingredients were piperonyl butoxide and pyrethrins. In the case of powders which

* Paid Paper.

[1] Name subsequently changed to piperonyl cyclonene.

also contained DDT, a suitable proportion of DDT wettable powder was first mixed with the required amount of inert carrier.[1]

HOUSE FLIES IN THE LABORATORY.—Plywood panels were sprayed with a water suspension of a dispersible powder containing 5 per cent piperonyl butoxide and 0.5 per cent pyrethrins at a dosage rate to give a uniform surface deposit of 50 mg. of piperonyl butoxide and 5 mg. of pyrethrins per square foot. The panels were kept in the laboratory at a temperature of 80°F. and relative humidity of 60 per cent, exposed to diffused light only. They were stored in racks during the interval between tests to prevent disturbing the deposits on the surface. The flies were exposed on the panels under stainless-steel cylinders that covered one-half square foot of area and were 4 inches in height. One end of the cylinder was closed with 16-mesh stainless-steel screening. Exposure was for the period required to knockdown all of the flies, or for 4 hours, whichever occurred first. Approximately 100 flies were used in each of three replications. After completion of the exposure, the flies were removed to chemically clean cages and given food and water to permit observations on mortality after 24 hours.

The results of tests conducted at 3, 5, 7, 11, 14, and 16 weeks after application of the surface deposits are shown in table 1. It will be noted that contact with the treated surfaces was sufficient to paralyze or to knockdown 100 per cent of the flies in 30 minutes up to the seventh week. In fact 100 per cent of the flies were knocked down in 30 minutes or less up to the tenth week, however, the effectiveness of the surface deposit began to decrease and after 14 weeks knockdown of 100 per cent was not attained in 4 hours.

Flies which were paralyzed (in 30 minutes or less) were incapacitated throughout the period of observation, as shown by the fact that there was little recovery up to 4 hours. Approximately two-thirds to over 90 per cent of the flies succumbed in 24 hours at all exposures including the fourteenth week. After the sixteenth week, 42 per cent of the flies were killed despite their exposure throughout the 4 hour period.

**Table 1.—Knockdown and mortality of houseflies exposed to surface application of water dispersible powder at the rate of 50 mg. of piperonyl butoxide and 5 mg. pyrethrins per square foot on plywood panels.**

| Elapsed Time After Application | Per cent Knockdown in: | | | | | Per cent Mortality 24 Hours |
|---|---|---|---|---|---|---|
| | 30 min. | 1 hr. | 2 hrs. | 3 hrs. | 4 hrs. | |
| One Day | 100 | 100 | 100 | 95 | 88 | 65 |
| Three Weeks | 100 | 100 | 100 | 100 | 100 | 98 |
| Five Weeks | 100 | 100 | 100 | 100 | 100 | 91 |
| Seven Weeks | 100 | 100 | 100 | 100 | 100 | 84 |
| Eleven Weeks | 92 | 92 | 100 | 100 | 100 | 72 |
| Fourteen Weeks | 33 | 51 | 88 | 94 | 94 | 71 |
| Sixteen Weeks | 22 | 44 | 55 | 61 | 61 | 42 |

FLIES ON CATTLE.—Laboratory tests by McAlister (1947) have shown that a water-dispersible powder in a spray applied on plywood panels to give surface deposits of 2 mg. of piperonyl butoxide, 0.2 mg. of pyrethrins, and 12.5 mg. of DDT gives residual effectiveness against house flies for a period as long as that obtained with a surface deposit of 100 mg. of DDT alone. The piperonyl butoxide-pyrethrins-DDT residue paralyzed the flies in less than one-fourth of the time required by the higher deposit of DDT alone. DDT is considered to be toxic to warm-blooded animals, and the advisability of its use on animals or feed to be consumed by animals could easily be questioned. The use of any material with DDT, however, that would permit reduction in the concentration and quantity of DDT required for effective control of insects appeared to be a step in the direction of lessening the potential dangers of DDT.

Three combinations of piperonyl butoxide, pyrethrins, and DDT in wettable powders were tested against flies on cattle

[1] (Usually *Celite 209*) and this mixture was impregnated with the piperonyl butoxide and pyrethrum extract, wetting and dispersing agents were added, and the powder then milled.

in Maryland. The powders contained the following proportions of active ingredients:

| *Powder A* | *Powder B* |
|---|---|
| 4 per cent Piperonyl butoxide | 2 per cent Piperonyl butoxide |
| 0.4 per cent Pyrethrins | 0.2 per cent Pyrethrins |
| 25 per cent DDT | 25 per cent DDT |

*Powder C*

2 per cent Piperonyl butoxide
0.2 per cent Pyrethrins
12.5 per cent DDT

The powders were suspended in water at the rate of 2 grams per 100 ml. (approximately 16 lb. per 100 gal.). The sprays were applied to individual cows at the rate of 12 ounces per animal. Each powder was used to spray 3 cows. The number of flies on each group of cattle before treatment and the daily observations after treatment are shown in table 2.

**Table 2.—Effectiveness of piperonyl butoxide-pyrethrins-DDT wettable powders against Flies on Cattle.**

| Powder | Number Before Treatment | | Number After Treatment | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 Day | | 4 Days | | 7 Days | |
| | Stable Flies | Horn Flies | Stable Flies | Horn Flies | Stable Flies | Horn Flies | Stable Flies | Horn Flies |
| A | 31 | 28 | 12 | 0 | 0 | 0 | 30 | 20 |
| B | 12 | 30 | 0 | 0 | 3 | 0 | 15 | 30 |
| C | 32 | 92 | 0 | 0 | 0 | 4 | 35 | 20 |

In this series of tests, there appeared to be no significant difference in effectiveness between the powder containing 25 per cent of DDT and that containing 12.5 per cent of DDT, if as much as 2 per cent of piperonyl butoxide and 0.2 per cent of pyrethrins are included. It is particularly noteworthy that the deposit of DDT on the animals can be markedly reduced from that usually recommended and still give effective control of flies on the cows.

Tests in Florida by Anderson[1] with the wettable powder containing 2 per cent of piperonyl butoxide, 0.2 per cent of pyrethrins, and 12.5 per cent of DDT used at 8 pounds per 100 gallons of water and applied as a spray at the rate of 1.5 pints per animal have confirmed the results obtained in Maryland.

A wettable powder containing 10 per cent of piperonyl butoxide and 0.5 per cent of pyrethrins was used in experiments on the control of horn flies on cattle. The first test was made on a herd of 53 cows which was sprayed at the rate of 1 pint per animal with a water suspension containing 8 pounds of the powder per 100 gallons. This application was effective in eliminating the initial population of horn flies present on the cows, but large numbers of flies were on the cows the next day. Another herd of 63 cows was sprayed at the same rate with a water suspension of 24 pounds of the powder per 100 gallons. The initial population of horn flies present on the animals at the time of spraying was eliminated and the cows remained free of flies for 3 days. An application of a spray containing 32 pounds of the powder per 100 gallons at the rate of 1 pint per animal did not increase the period during which the cows remained free of flies.

JAPANESE BEETLE ON SWEET CORN.—The wettable powder containing 2 per cent of piperonyl butoxide, 0.2 per cent of pyrethrins, and 12.5 per cent of DDT was also used in tests for the control of the Japanese beetle on sweet corn. The powder was prepared as a suspension in water at the concentration of 16 pounds per 100 gallons, and the diluted suspension was applied at the rate of 1 gallon per 100 linear feet of row. The spray was applied only to the silks which were being severely attacked by the beetles.

Before the application of the spray the silks on 90 per cent of the ears were being so severely eaten by Japanese beetles that successful pollination could not have been completed. On examination 24 hours after spraying, hundreds of dead beetles were on the ground under each row, and all of the ears in the sprayed plots were free of beetles. Despite the fact that the Japanese beetle was at the height of prevalence in the area, the

[1] Anderson, C. V. (of the Entomological Research Laboratory of the J. R. Watkins Company), Personal communication.

treated corn remained free of beetles for 1 week. This period was sufficient to permit completion of pollination and the production of a good crop of corn.

Beans of the margins of cornfields, grapevines, and pigweed, a favored host of the Japanese beetle, were also sprayed with the same wettable powder used at a concentration of 16 pounds per 100 gallons. The initial application killed all of the beetles present, and no beetles succeeded in establishing on the sprayed plants for a period of 9 days. Several days with light to heavy rainfall occurred during this period. Foliage on unsprayed plants in the same area was practically consumed by the beetles.

SUMMARY.—The effectiveness of piperonyl butoxide with small quantities of pyrethrins, as previously demonstrated in sprays and liquefied-gas aerosols, has been further confirmed by using the same ingredients in wettable powders. Wettable powders are particularly effective in residual or surface sprays. Surface deposits from a wettable powder of 50 mg. of piperonyl butoxide and 5 mg. of pyrethrins per square foot on unfinished plywood panels in laboratory tests gave 100 per cent knockdown of house flies in 30 minutes or less through the tenth week after application, and from 60 to over 90 per cent mortality through the fourteenth week. A water suspension of a powder containing 10 per cent of piperonyl butoxide and 0.5 per cent of pyrethrins at a concentration of 24 pounds per 100 gallons applied at the rate of 1 pint per animal kept cows free of horn flies for a period of 3 days. Wettable powders containing small quantities of piperonyl butoxide and pyrethrins with about one-fourth the quantity of DDT usually recommended controlled horn flies and stable flies on cattle for 6 days, and the same powder applied as a spray to the silks of sweet corn prevented attack by the Japanese beetle during the period of pollination.—12-1-47.

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# ERRATUM

"Comparative Residual Effectiveness of Organic Insecticides Against House Flies and Malaria Mosquitoes"—R. W. Fay, E. L. Cole, and A. J. Buckner—JOUR. ECON. ENT. 40: 635–40, 1947.

In Table 1 information on residual toxicity of 0.25 per cent pyrethrins +5 per cent piperonyl cyclohexenone at a dosage of 4 c.c. per sq. ft. should be changed to show kills of 85, 87, 79, 59, 56, and 70 per cent respectively after 4, 16, 24, 28, 32, and 36 weeks of aging. Information on 0.025 per cent pyrethrins+0.5 per cent piperonyl cyclohexenone applied at 4 c.c. per sq. ft. should be changed to show kills of 60, 46, and 23 per cent respectively after 4, 16, and 24 weeks. Kills as cited in the JOURNAL were from 30-minute exposures which were inadvertently placed in the table in lieu of the results obtained from 60-minute exposures.

In the summary, the statement that these compounds "were tested at the manufacturer's recommendation," is misleading since it has been called to our attention that dilution directions furnished were for use as space sprays and not for residual effect. Failure to obtain a residual effect at "space spray" concentrations does not preclude residual qualities at higher dosages. When used at 200 milligrams per square foot of surface area, a good residual action was obtained for 23 weeks against *Anopheles quadrimaculatus*.

# SCIENTIFIC NOTES

## Effect of Sublethal Dosages of Pyrethrum on Oviposition of the Cigarette Beetle

JOSEPH N. TENHET, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

During the period 1940–1945 extensive experiments were conducted with pyrethrum-oil sprays in tobacco warehouses at Richmond, Virginia. In the course of these experiments tests were made of various dosages and strengths of spray. In 1941, when the cigarette beetle, *Lasioderma serricorne* (F.), was used as a test insect, it was observed that beetles that had been exposed to spray did not deposit so many eggs as did unsprayed beetles. As a result of this observation records were maintained of the egg deposition of sprayed and unsprayed beetles over a 5-year period.

The adults of the cigarette beetle are resistant to pyrethrum. Upon exposure to a pyrethrum spray knock-down was rapid, but in the course of time many of the insects recovered. In all experiments records of mortality were made 5 days after spraying. All insects able to fly or crawl readily were considered as alive, and those unable to fly or crawl normally were arbitrarily considered as dead.

During spray tests in tobacco warehouses the cigarette beetles were confined in fine-mesh wire cages placed at random locations in a warehouse. Usually four cages of cigarette beetles (25, 50, or 100 beetles to each cage) were exposed in each test, one cage near the center aisle of the building and about 10 or 11 feet above the floor, one near the center aisle and 1 to 2 feet above the floor, one near the rear wall of the storage building and 8 to 10 feet above the floor, and one near the rear wall on or near the floor. In 1941 this general plan was varied so that two cages were always placed near the windward side of the warehouse and two near the leeward side.

The test insects used in all experiments were reared in the laboratory under controlled conditions and were as nearly uniform as possible. An effort was made to select newly matured individuals, but the age of cigarette beetle adults cannot always be determined and doubtless older individuals were sometimes selected—perhaps females which had already deposited many of their eggs. However, the sprayed and unsprayed beetles were of approximately the same age, as they were taken from the same culture. Hence they were comparable as to their age and the number of eggs in the ovaries of the females. In all tests the ratio of males to females was unknown. It is very difficult to distinguish between the sexes, but, since the beetles were selected at random and large numbers were used over a prolonged period, the sex ratio should have remained constant between sprayed and unsprayed lots.

After exposure to the spray all cages were removed to the laboratory and a small section of the midrib of a tobacco leaf was placed in each cage. (The cigarette beetle usually oviposits in tiny cracks and crevices. One of its favorite places is a fold or wrinkle in the midrib of a tobacco leaf.) Sections of midrib about 1 inch long were split in half. The two halves were then held firmly together with a paper clip. When such sections were introduced into a cage of cigarette beetles, the females deposited their eggs on them, usually between the halves. At the end of the period of observation the halves of the stem were separated and the eggs counted under a binocular microscope.

The ratio of oviposition of the sprayed to that of the unsprayed beetles was computed on the basis of the number of surviving beetles in each cage. Thus, if a test lot of 100 beetles had a mortality of 35, the number of eggs deposited was attributed to the 65 surviving beetles. It is recognized that this method of computation may not be entirely accurate, as it is possible that some females may have deposited eggs prior to death. However, all or most of the beetles exposed to the insecticide were quickly paralyzed, and it is believed that those which died never recovered sufficiently to lay eggs.

The data on 5 experiments extending over 3 years during which 51 tests were conducted, each test in a different warehouse or on a different date, are shown in table 1. Cigarette beetles surviving exposure to a pyrethrum-oil spray consistently deposited fewer eggs than untreated beetles, the difference ranging from 25 to 68 per cent. On an average, beetles not exposed to spray deposited more than twice as many eggs as surviving beetles that had been exposed.

Just how sublethal dosages of pyrethrum reduced oviposition of the cigarette beetle is not known. It is known that pyrethrum tends to paralyze an insect's appendages. A partial paralysis often persists

**Table 1.—Effect of sublethal dosages of pyrethrum-oil spray on the oviposition of the cigarette beetle. Richmond, Va.**

| Date | Beetles Used in Tests Total | Per Cent Mortality | | Insects Surviving Test | | Egg Deposition | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Eggs per Beetle | |
| | | Sprayed | Unsprayed | Sprayed | Unsprayed | Sprayed | Unsprayed | Sprayed | Unsprayed |
| 1941 | 4700 | 15.3 | 5.1 | 1947 | 2277 | 1134 | 2269 | 0.582 | 0.997 |
| 1942 | 4200 | 34.3 | 12.1 | 1379 | 1845 | 1894 | 4545 | 1.373 | 2.463 |
| 1942 | 675 | 22.2 | 13.3 | 350 | 195 | 103 | 130 | 0.294 | 0.667 |
| 1945 | 2400 | 18.9 | 9.6 | 1298 | 723 | 723 | 835 | 0.869 | 1.156 |
| 1945 | 1250 | 37.3 | 8.4 | 627 | 229 | 282 | 320 | 0.449 | 1.397 |
| Total or Average | 13,225 | 24.4 | 8.8 | 5,601 | 5,269 | 4,136 | 8,099 | 0.738 | 1.537 |

indefinitely, even though the insect may recover sufficiently to fly and crawl. It is suggested that the failure to deposit eggs may have been due to paralysis, or partial paralysis, of the genitalia.

SUMMARY AND CONCLUSION.—In experiments wherein large numbers of the cigarette beetle, *Lasioderma serricorne* (F.), were exposed to sublethal dosages of pyrethrum spray, it was shown that surviving beetles deposited only about half as many eggs as beetles not exposed to such spray. Consequently, the control of the cigarette beetle in tobacco warehouses was consistently better than was indicated by the mortality data from lots of test insects. For example, if a spray killed 50 per cent of the cigarette beetles present and also reduced by 50 per cent the number of eggs deposited by the surviving beetles, the total effect was equivalent to a 75 per cent reduction in population.—7-18-47.

## The Tail Louse in Florida

JOHN T. CREIGHTON, and N. M. DENNIS,[1] *University of Florida, Gainesville*

The first recorded collection of the tail louse in the United States was made by the senior author in early June 1944 when a complaint was received from Vero Beach. This collection was made from a Jersey dairy herd, and a range cattle herd located at Vero Beach in Indian River County. According to Knipling the Bureau of Entomology and Plant Quarantine made its first observations and collections in the United States during August 1945 in Orange County, Florida. Due to a lack of literature and faulty identification this species was not correctly identified until the Spring of 1947 when C. F. W. Muesebeck identified specimens as *Haematopinus quadripertusus* Fahrenholz.

The original description of this species was made by Fahrenholz. There are no other references to this species in the literature which Muesebeck has indicated may be due to misidentification upon the part of field workers (Fahrenholz 1916).

Since making the original collections in Indian River County the authors have made collections from dairy herds in Broward County, from beef cattle herds in Alachua County, from dairy herds in Alachua County and from the Raiford Prison Farm Angus herd in Bradford County. This indicates a rather wide distribution of this species in Florida.

The Florida cattle owners that have experienced attacks of this species in their herds fear the presence of this insect. When populations of the insect reach high intensity they have a very devitalizing effect upon the animals attacked. In the fall of 1945 the senior author made observations on a yearling Hereford herd that had been brought in from the Paines Prairie range near Gainesville. Ordinarily animals feeding on this range during the summlr months attain an excellent condition. These animals were emaciated, which was apparently due entirely to the presence of the tail louse. It is a species of unquestioned economic importance in Florida.

The cattle tail louse (Fig. 1) is a comparatively large species. The average body width of the adult is 2.3 millimeters, while the average length is 4.4 mm. The head, thorax, and legs are metallic brown in color. The antennal segments have a brown base and the distal end of each segment is dirty-white in color. The abdomen has a greasy gray appearance with a white line along the dorsum. Sclerotic oval areas along either side of dorsal white line appear as brown spots. The distal extremity of legs are equipped with strongly developed ungues.

The adult lice are usually found in the bush of the tail where they are feeding and depositing eggs. Thus the name tail lice. The eggs (Fig. 2) are glued to the hairs of the tail and are usually deposited in great numbers. Though this species is commonly called the tail louse the entire life is not spent on the tail. Following eclosion the nymphs usually migrate up the tail and come to rest near the external openings of the animals genital and digestive tracts. They may be found in great numbers near the anus and the vulva, where the excretions and tenderness of skin seem to facilitate their development. Likewise the nymphs may migrate up the spine and may be found in numbers on the head of the animal around the eyes, feeding on or near the eyelids. Infrequently they will be found upon other regions of the body. The adults are usually on the tail but may be found on other parts of the body, even the eyes.

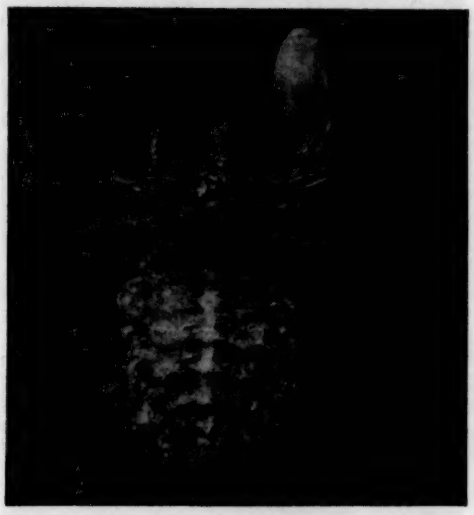

FIG. 1.—Adult tail louse.

This species reaches its greatest abundance during the late summer and early fall. Extremely cold periods during winter months seem to reduce the population on cattle, in the Alachua County area, to a point of almost complete extermination. Climatic and weather factors will doubtless play a definite part in the economic importance of this species in the United States.

Studies pertaining to the control of the species were initiated in June 1945 and have been continued. Initial observations pertaining to the louse seemed to indicate that infestations were rather localized on the tails of the cattle. Herd tests were undertaken in which the tails of all the animals were sprayed thoroughly. Three herd tests were conducted. The first was treated with an emulsive type of spray formulation in which DDT and *Thanite* were incorporated as toxicants. The field dilution spray contained *Thanite* at a 2-per cent strength and DDT at 0.2 per cent. Only the tails were treated and these were wet thoroughly. Population

[1] R. E. Dixon cooperated in the conduct of the experiment, and Prof. Millidge Murphy, Jr., prepared the photographs.

counts after a lapse of 24 to 48 hours revealed good toxic effects upon the adult lice. Counts after 2 weeks revealed general reinfestation of the majority of cattle used in the tests. Another herd test was made in which an emulsive *Thanite* formulation was employed in which the *Thanite* was used at 5 per cent. The tails were treated as previously described. This treatment resulted in complete elimination of the lice from the tails but reinfestation occurred after a period of a week.

The third herd test consisted of another tail application in which the tails were thoroughly treated with a DDT spray which was prepared from an emulsive concentrate. The field dilution contained 3 per cent DDT. Initial toxic effects were excellent reaching 100 per cent, but reinfestation of tails occurred after a period of 3 weeks.

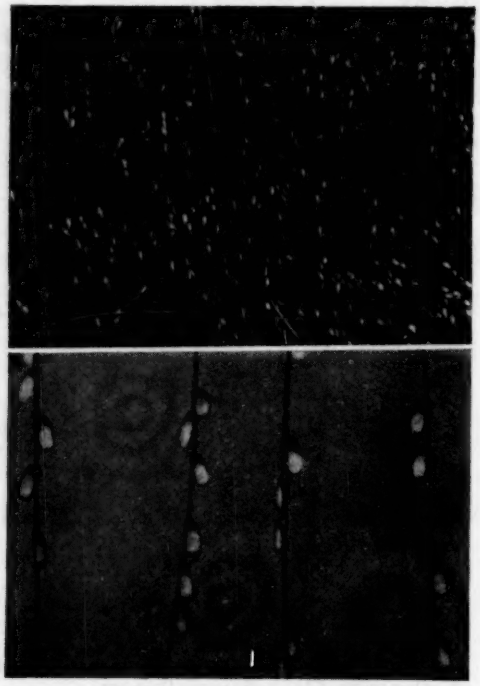

FIG. 2.—Eggs of tail louse.

Following the initial herd tail tests it was revealed that the lice were distributed along the spine to the head and under the tail near the external openings of the digestive and reproductive tracts. Herd tests were then made in which the body of each animal, with the exception of the heads, were sprayed with sprays identical with those used in the preliminary tests. These tests gave good initial control but reinfestation was general after a period of a month.

A final series of tests have been conducted in which sprays of wettable DDT, emulsive DDT, and a combination of pyrethrin-rotenone were compared. The wettable powder and emulsive DDT formulations were diluted to produce field sprays containing 1.0 per cent DDT, and 2 per cent DDT. The pyrethrin-rotenone spray contained pyrethrins I at 0.37 per cent strength and derris concentrate at 0.32 per cent, in an alcohol base. Applications of all formulations were thorough on all regions of the body including the skin area around the eyes. These three spray formulations had excellent toxic effects upon all lice on the animals sprayed. Protection was extended over a period of several weeks.

Results of tests conducted indicated that the cattle tail louse may be successfully controlled by the use of several toxicant materials including DDT, *Thanite*, pyrethrins, and rotenone. It is clearly evident that one of the most important factors in control is effective coverage including a thorough wetting of the tail and all areas of the body including the head. Special attention should be given the tails, spine, external openings of the reproductive and digestive tracts, and the eyes. For example a thorough application of a 2 per cent DDT spray applied to all animals in a herd would doubtless result in a complete elimination. However, the authors feel that a follow-up application within 21 to 28 days would be economical. It is believed that herd treatments in early spring would result in improved animal condition during late spring, summer, and fall.

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## Milky Disease Infecting *Cyclocephala* Larvae in the Field

RALPH T. WHITE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Thousands of larval surveys have been made in connection with studies of the milky diseases of the Japanese beetle, *Popillia japonica* Newm. During the course of these surveys numerous instances of infection among other scarabaeid larvae with organisms at least similar to those causing type-A and type-B milky diseases of the Japanese beetle, described as *Bacillus popilliae* Dutky and *B. lentimorbus* Dutky (Dutky 1940), respectively, have been recorded. A preliminary report was published in 1941 on the susceptibility of certain scarabaeid larvae to infection of type-A milky disease by injection as well as by inoculation of the soil (Dutky 1941).

Numerous reports on the behavior of organisms causing milky diseases among Japanese beetle populations in the field have been published (White 1940, 1941, 1946; White & Dutky 1940).

Although many species of scarabaeid larvae have been shown to be susceptible to milky disease, this paper is limited to a presentation of verified records of infected larvae of the genus *Cyclocephala* found in the field. No attempt has been made to separate the larval forms of *Cyclocephala borealis* Arrow and *C. immaculata* Arrow, the most prevalent species, since no taxonomic characters have been found to do this satisfactorily. It is probable, however, that most of the records herein are of *C. borealis*.

The locations at which *Cyclocephala* larvae definitely infected with milky disease have been found are listed in table 1. In most instances the causal agent was an organism similar to type A, which was originally designated as atypical type A, but more recently as type A (*Cyclocephala* strain).

[1] P. J. McCabe assisted in the field surveys, and S. R. Dutky, T. N. Dobbins, and J. V. Thompson made the microscopical examinations to verify the type of organism present.

**Table 1.—Record of field collections of *Cyclocephala* larvae infected with milky disease.**

| LOCALITY AND SITE | DATE OF COLLECTION | NUMBER OF INFECTED LARVAE COLLECTED |
|---|---|---|
| Connecticut: New Haven,[1] East Rock Park | June 26, 1942 | 1 |
| Delaware: Marydel area, pasture near Maryland State line | March 25, 1943 | 1 |
| District of Columbia: | | |
| Anacostia, golf course | Each fall and spring since 1940 | [2] |
| Blue Plains, filtration plant | December 9, 1940 | 1 |
| Constitution Avenue, Department of Interior lawn | September 4, 1941 | 1 |
| Foxhall Village, lawn | October 30, 1941 | 2 |
| The Mall, turf | August to October 1941; June 1942 and 1943 | [2] |
| Rock Creek Park, between Military and Broad Branch Roads | June 5, 1946 | 1 |
| West Potomac Park, old golf course | June 14, 1940 | 1 |
| Maryland: | | |
| Landover, Prince Georges Country Club | May 3, 1943 | 2 |
| Silver Spring, Indian Spring Golf Club | May 26, 1944 | 2 |
| Marydel area, pasture near Delaware State line | March 25, 1943 | 1 |
| Perry Point, Veterans' Hospital | September 8, 1939; October 24, 1946 | 1<br>1 |
| New Jersey: | | |
| Cape May, Cape May Golf Course | November 6, 1946 | 1 |
| Moorestown, Bureau laboratory lawn | Spring 1945 | [3] |
| Tavistock, Country Club | November 7, 1946 | 1 |
| Wildwood, Country Club | November 6, 1946 | 2 |
| Woodcrest, Country Club | August 26, 1943 | 1 |
| New York: | | |
| Yorktown Heights, Mohansic Golf Course | August 10, 1944 | 1 |
| Mahopac, Lake Mahopac Golf Course | October 3, 1945 | 1 |
| Pennsylvania: | | |
| Forest Hills, pasture | September 10, 1943 | 1 |
| Jenkintown, Old York Road Country Club | November 13, 1946 | 1 |
| Philmont, Country Club | November 14, 1946 | 4 |
| Virginia: | | |
| Arlington National Cemetery, Tomb of the Unknown Soldier | August 19, 1942 | 1 |
| Arlington, Columbia Island area parkway | May 15, 1946 | 1 |
| Arlington, Washington Golf and Country Club | June 1, 1943 | 1 |
| Cheriton, Baldwin estate | May 21, 1941 | 1 |
| Fort Belvoir, Army base golf course | October 30, 1944 | 1 |
| Mount Vernon, entrance circle | Spring 1940 | [4] |
| | Fall 1940 | [5] |
| West Virginia: Weirton, Williams Country Club | October 1938 | [6] |

[1] One additional infected larva collected by J. P. Johnson, site unknown.
[2] Consistent collections of infected grubs.
[3] A number of infected *C. borealis* larvae collected.
[4] Population heavy, many milky larvae. Report of A. E. Rabbitt, formerly with the National Park Service, U. S. Department of the Interior.
[5] Population very low; several milky larvae recovered.
[6] Population heavy; several larvae developed milky disease when held in soil from the golf course.

From the number and range of collection points it seems probable that organisms causing milky diseases among *Cyclocephala* larvae are rather common. This seems even more likely when it is realized that the records of field-infected larvae were scattered throughout 8 states and the District of Columbia, and were obtained more or less accidentally in connection with surveys made for the Japanese beetle.

Although no detailed study has been made to determine the effectiveness of milky disease as a control for *Cyclocephala* and other native white grubs in the field, one instance in which a severe infestation of *C. borealis* was controlled by disease seems worth recording.

During the fall of 1941 a heavy larval population of the Japanese beetle was present in a portion of the Mall in the District of Columbia. On September 3 and 4 enough *Cyclocephala borealis* larvae to cause severe turf injury were also found generally distributed throughout this area. Gross examinations showed approximately 17 per cent of these larvae to be milky. Microscopic examinations showed the *Popillia* larvae to be infected with the regular type-A organism whereas the *Cyclocephala* larvae were infected with atypical type-A, an indication that both organisms were present and working independently. Many of the *Cyclocephala* larvae were also parasitized by an undetermined hymenopterous species. In October the disease rate among the *Cyclocephala* larvae was found to be about 12 per cent. By the following spring few *Cyclocephala* larvae could be found, and no concentrated larval popula-

tion has since occurred in this area. In subsequent years only an occasional diseased *Cyclocephala* larva has been found.

In view of these observations it seems possible that milky disease may be playing an important role in checking sporadic infestations of *Cyclocephala* in many places.—9-12-47.

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## A Chemical Treatment of Soil Which Produces Plant Tissue Lethal to European Corn Borer[1]

D. D. QUESTEL and R. V. CONNIN, *U.S.D.A., Bureau of Entomology and Plant Quarantine, Agr. Res. Adm.*

An investigation was begun in the summer of 1944 to find a chemical which, when placed in the soil at the time of corn planting or during the growing period, would be taken up into the stalk and leaves to serve as protection from attack by the European corn borer, *Pyrausta nubilalis* (Hbn.). Some promise was shown by a few of several hundred chemicals tested, but the most striking results were obtained in the spring of 1947 with 0,0-diethyl 0-*p*-nitrophenyl thiophosphate. The procedure employed in these preliminary trials and the results obtained are described in this paper.

On May 19, 1947, six kernels of corn were planted in each of ten 5-inch flower pots in soil that had been mixed with 2 grams of 0,0-diethyl 0-*p*-nitrophenyl thiophosphate per pot. These plants were grown during May and June in an unheated greenhouse. Three weeks after planting, when the corn had reached a height of 6 to 8 inches, leaves were cut into sections approximately 1 inch long and placed in 0.5 by 4-inch test tubes. Four of the leaf sections were placed in each tube together with two corn borer egg masses in the blackhead stage. The stalks of plants from which the leaves had been removed were placed in other tubes. Two or three sections of stalk each about 1 inch long, split at one end to allow entry of the larvae, were placed in each tube. The results of these tests are shown in table 1.

**Table 1.—Mortality of newly hatched European corn borer larvae confined on sections of corn plants grown in soil treated with 0,0-diethyl 0-*p*-nitrophenyl thiophosphate just before planting.**

| Portion of Plant | Feeding Period | Amount of Feeding | Tests | Average Larvae per Test | Larvae Dead |
|---|---|---|---|---|---|
| | *Hours* | | *Number* | *Number* | *Per Cent* |
| Leaves: | | | | | |
| Treated | 48 | Little | 3 | 80 | 99 |
| | 24 | Very little | 1 | 308 | 94 |
| Untreated | 48 | Much | 1 | 43 | 0 |
| | 24 | Much | 1 | 144 | 3 |
| Stalks: | | | | | |
| Treated | 48 | Very little | 3 | 58 | 100 |
| | 24 | None | 1 | 318 | 100 |
| Untreated | 24 | Much | 1 | 154 | 3 |

Since the sections of leaves were taken from points on the plant well above the surface of the soil, and since no insecticide was applied subsequent to planting, it appears very unlikely that the leaf surfaces and stems bore any of the insecticide, but rather that the toxic agent causing the high mortality shown in table 1 was taken up through the plant roots. Most of the larvae were killed within the first 24 hours after hatching. They fed very little on the leaf or stem sections from treated plants, but did feed heavily on such sections from plants grown in untreated soil.

The effect of treating soil with this phosphorus compound was determined by watering another series of plants 3 to 4 inches high with a suspension containing approximately 2 grams of 0,0-diethyl 0-*p*-nitrophenyl thiophosphate per pot. Tests to determine the toxicity of sections taken from the leaves and stalks of these plants were conducted 1 and 2 weeks after the soil treatment. Care was taken that no parts of the plants were used for testing which had come in direct contact with the water suspension used in the treatment. The results are shown in table 2.

The results obtained at the end of 1 week indicate that the leaves were relatively non-toxic, probably because of the short time between the application of the water suspension to the soil and the testing, although mortality was high in the tubes containing the stalk sections. In the tests made a week later, however, all the larvae feeding on either leaves or stalks were killed. These results, together with those presented in table 1, indicate that the toxic agent or some derivative of it was absorbed by the roots and was being circulated through the plants, and that this action was progressive.

[1] The 0,0-diethyl 0-*p*-nitrophenyl thiophosphate used in these experiments was supplied by the American Cyanamid Company under the designation "Experimental Insecticide 3422." The insecticidal properties of this chemical were discovered in the research laboratories of I. G. Farbenindustrie, Elberfeld, Germany, where it was designated as E-605. Some of the entomological results obtained in Germany are given in B.I.O.S. Final Report No. 1095, Item No. 22, May–June 1946, entitled "Developments in Methods and Materials for the Control of Plant Pests and Diseases in Germany," by H. Martin and H. Shaw, and in FIAT Final Report No. 949, October 14, 1946, entitled "Organic Chemical Intermediates for Insecticides, Fungicides and Rodenticides," by J. T. Thurston (abstract in U. S. Dept. Com. Bib. Sci. Indus. Rpts. 5: 755, 1947). Copies of these reports may be obtained through the Department of Commerce, Washington 25, D. C.

**Table 2.—Mortality of newly hatched European corn borer larvae confined on sections of leaves and stalks of corn plants grown in soil watered with a suspension of 0,0-diethyl 0-*p*-nitrophenyl thiophosphate after the plants were 3 or 4 inches high. (Feeding period 48 hours.)**

| Portion of Plant | Amount of Feeding | Tests | Average Larvae per Test | Larvae Dead |
|---|---|---|---|---|
| | | *Number* | *Number* | *Per cent* |
| *Tests one week after treatment* | | | | |
| Leaves: | | | | |
| Treated | Much | 4 | 51 | 5 |
| Untreated | Much | 3 | 48 | 3 |
| Stalks: | | | | |
| Treated | Little | 3 | 44 | 96 |
| Untreated | Much | 3 | 50 | 3 |
| *Tests two weeks after treatment* | | | | |
| Leaves: | | | | |
| Treated | None | 1 | 111 | 100 |
| Untreated | Much | 1 | 37 | 11 |
| Stalks: | | | | |
| Treated | None | 1 | 48 | 100 |
| Untreated | Much | 1 | 25 | 0 |

Several young corn plants growing in soil treated with 2 grams of the insecticide per pot just before plantings were infested with corn borers. Approximately 300 eggs in the blackhead stage were placed on the plants in each pot. Plants growing in untreated soil were infested with a like number of borers at the same time. The resulting larvae on the treated plants fed very little and many of them died on the leaves, whereas many of those on the untreated plants fed normally and none of them died on the leaves, although most of them crawled off because of overcrowding.

The compound caused no observable injury to the growing corn plants in any of the tests. On the contrary, it appeared to be somewhat beneficial to them. However, no information is available concerning the effects of this chemical on seeds, on the growth and fruiting ability of plants growing in treated soils, and on the minimum quantities necessary to render plants toxic to the insects feeding on them. Information is also lacking on the identity, amounts, and persistence in soils and plants of the chemical, or such derivatives of it as may be produced by reactions with soil and plant constituents, and the toxicity of treated plants to warm-blooded animals that may eat them.

## Boxelder Bug Nymphs Feeding on Dead Honeybees

GEORGE F. KNOWLTON, *Utah Agricultural Experiment Station, Logan*

On several occasions, the writer has observed adult boxelder bugs, *Leptocoris trivittatus* (Say), feeding on recently dead and on nearly dead honeybees, in Utah. On May 29, 1947, this was again observed in a beeyard approximately 7 miles southwest of Sandy, Utah, in Salt Lake County. In this instance one adult boxelder bug was feeding on a moribund worker honeybee, which occasionally would weakly move a leg.

On May 30, 1947, while visiting a beeyard at the edge of a scrub-oak patch about two miles east of Clear Lake, in the foothills south of Payson, Utah three nymphal *Leptocoris trivittatus* were observed to be feeding on a recently dead worker honeybee. A few minutes later, Mr. Ronald Belliston, owner of the bees, called my attention to six of the red boxelder bug nymphs feeding on another honeybee. In still a third case, two nymphs were feeding on a recently dead worker bee. These nymphal bugs all continued their feeding during the approximately 20 minutes that the writer spent in this beeyard.

None of my observations have indicated that the boxelder bug will attack or kill an active honeybee. However, their feeding upon very much weakened and on dead honeybees, and on individuals of their own species in similar devitalized physical condition, appears to be not uncommon. It seems likely that all, or practically all bees fed on were beyond chance of recovery before boxelder bug feeding occurred.—8-18-47.

## Parathion for Control of Green Peach Aphid on Shade-Grown Tobacco

JOHN T. CREIGHTON, and WILLIAM B. GRESHAM, JR.
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The southern shade grown tobacco industry is located in northwest Florida and southern Georgia. This industry controls the economy of this district. Here some 4000 to 6000 acres of land are devoted to the culture of tobacco under cheesecloth shades. The harvested leaf is used as wrapper tobacco in the manufacture of cigars. The income to the growers is 10 to 14 million dollars annually.

This tobacco industry has been threatened with disaster several times when diseases and other factors have limited the production of grade A leaf. In 1946 the green peach aphid, *Myzus persicae* (Sulz), appeared on shade-grown tobacco in northern Florida and southern Georgia belt. In 1947 this insect species reached epidemic numbers and threatens to curtail or stop the culture of tobacco unless a satisfactory control is discovered. During the 1947 season losses varied from negligible damage to complete distruction, with the greater part of the crop affected. Growers and manufacturers are deeply concerned over the future of this industry.

The green peach aphid has been known in the United States for many years, and has been a pest of a wide range of plants, including vegetables, deciduous fruits, flowering plants, and ornamental shrubs. It was not until 1946 that this species appeared on shade-grown tobacco in sufficient numbers to cause concern. In 1947 it is looked upon as the greatest danger that has ever devolved upon this industry.

The authors initiated control studies in the northwest Florida shade-grown tobacco district during the early spring of 1947. These tests are continuing.

The standard recommendation for the control of this aphid has been nicotine sulfate as a spray or dust. Three per cent nicotine dust proved to be quite ineffective in initial tests. The chemical which proved most promising during 1947 was only released for investigation in February 1947. This was ortho, ortho-diethyl ortho-para-nitrophenyl-thiophosphate, known by the common name parathion.

This chemical was released to research workers as "experimental insecticide 3422." It is a deep brown liquid very slightly soluble in water. However, it is completely miscible in the majority of organic solvents, including alcohols; acetone and cyclohexanone; esters, such as acetates, phthalates, abietates, animal and vegetable oils; ethylene glycols; ethylether; and polymethylated naphthalenes. It is only slightly soluble to insoluble in petroleum ether, kerosene, and refined spray oils.

Parathion may be formulated into emulsions, dusts and wettable powders. It should not be used with strongly alkaline materials.

The manufacturers[1] have found it effective under laboratory conditions in the control of a wide range of insect species including roaches, houseflies, thrips, scales, plant bugs, armyworms, and Mexican bean beetles.

The new material should be applied with normal precautions as it is toxic to warm blooded animals. It seems to have a safe range on a number of plants especially when used as a wettable powder or dust.

The investigations in northwest Florida which included this compound were some of the first field tests conducted. Dusts containing parathion at a .5 and 1.0 per cent level were employed and plant injury was not noticeable on young or mature foliage.

PRELIMINARY INVESTIGATIONS.—In the preliminary investigations only five plants were used in each plot and sufficient buffer area was established between plots. The largest terminal leaf was selected for making infestation and post application counts. Total number of aphids on selected leaves were recorded. The method used in determining the populations on leaves was as follows:

| LETTER | NUMBER OF APHIDS | MEDIAN |
|---|---|---|
| X | 1 to 5 | 3 |
| Y | 6 to 25 | 16 |
| Z | 26 to 50 | 38 |
| A | 51 to 100 | 75 |
| B | 101 to 200 | 150 |
| C | 201 to 300 | 250 |
| D | 301 to 500 | 400 |
| E | more than 500 | 600 |

The dusts were applied with hand duster and distributed uniformly on the foliage.

In the plot treated with 1 per cent parathion approximately 90 to 95 per cent of the aphids had dropped from the plant within 60 to 90 minutes. They were dead within 12 hours. The results follow:

| PLANT | PRE-TREATMENT COUNTS | POST-TREATMENT COUNTS |
|---|---|---|
| 1 | 250 | 0 |
| 2 | 400 | 0 |
| 3 | 400 | 0 |
| 4 | 400 | 0 |
| 5 | 400 | 0 |

Thus is revealed a 100 per cent control. Hexaethyl tetraphosphate was also used in this preliminary series of tests and had similar toxicity. However, a severe foliage burn resulted from the application of this chemical. This insecticide was applied as a liquid spray.

[1] American Cyanamid and Chemical Company.

The green peach aphid lives on the lower surface of the tobacco leaves. In one test the dust of the new chemical was applied only to the upper leaf surfaces. The insect toxicity approached 100 per cent.

FIELD TESTS.—*Experiment 1.* Four blocks were established containing plots 52 feet square. Sufficient buffer areas were provided. Plants near the center of plots were selected for counts, and population estimates were made in a manner similar to that used in the preliminary test. Results were as follows:

| PLANT NUMBER | PRE-TREATMENT COUNTS | POST TREATMENT COUNTS | |
|---|---|---|---|
| | | 8 hrs. | 24 hrs. |
| **BLOCK I** | | | |
| 1 | 400 | 38 | 0 |
| 2 | 600 | 3 | 0 |
| 3 | 400 | 38 | 0 |
| 4 | 600 | 38 | 0 |
| 5 | 250 | 38 | 0 |
| **BLOCK II** | | | |
| 1 | 600 | 3 | 0 |
| 2 | 600 | 3 | 0 |
| 3 | 400 | 3 | 0 |
| 4 | 400 | 3 | 0 |
| 5 | 250 | 3 | 0 |

*Experiment 2.* In experiment 2 the plots consisted of nine rows which were 75 feet in length. Replications were not provided. Plot 1 was treated with a 1.0 per cent parathion, and plot 2 with a 0.5 per cent dust. Results follow:

| PLANT | PRE-TREATMENT COUNTS | POST-TREATMENT COUNTS 24 hours |
|---|---|---|
| **PLOT 1** | | |
| 1 | 150 | 0 |
| 2 | 150 | 0 |
| 3 | 150 | 0 |
| 4 | 150 | 0 |
| 5 | 150 | 0 |
| 6 | 75 | 0 |
| 7 | 75 | 0 |
| 8 | 38 | 0 |
| 9 | 75 | 0 |
| 10 | 15 | 0 |
| 11 | 15 | 0 |
| 12 | 15 | 0 |
| 13 | 400 | 0 |
| 14 | 150 | 0 |
| 15 | 250 | 0 |
| **PLOT 2** | | |
| 1 | 75 | 2 |
| 2 | 75 | 0 |
| 3 | 75 | 3 |
| 4 | 75 | 15 |
| 5 | 38 | 15 |
| 6 | 38 | 3 |
| 7 | 75 | 0 |
| 8 | 75 | 3 |
| 9 | 15 | 0 |
| 10 | 38 | 0 |
| 11 | 38 | 0 |
| 12 | 75 | 0 |
| 13 | 5 | 0 |
| 14 | 75 | 0 |
| 15 | 75 | 0 |

*Experiment 3.* Test plots in experiment number 3 were approximately 9000 square feet. Dusts were applied with mule-drawn traction duster. The coverage was imperfect especially with the 0.5 per cent dust. Plot 1 was treated with a 1.0 per cent parathion dust, while plot 2 was treated with a 0.5 per cent dust. Results were as follows:

| Plant | Pre-Treatment Counts | Post-Treatment Counts 24 hours |
|---|---|---|
| | PLOT 1 | |
| 1 | 150 | |
| 2 | 400 | |
| 3 | 38 | 0 |
| 4 | 400 | 3 |
| 5 | 400 | 0 |
| 6 | 400 | 3 |
| 7 | 250 | 3 |
| 8 | 400 | 3 |
| 9 | 400 | 0 |
| 10 | 250 | 0 |
| 11 | 38 | 0 |
| 12 | 400 | 0 |
| 13 | 400 | 0 |
| 14 | 150 | 0 |
| 15 | 250 | 0 |
| 16 | 400 | 0 |
| 17 | 400 | 0 |
| 18 | 400 | 0 |
| 19 | 400 | 0 |
| 20 | 150 | 0 |
| | PLOT 2 | |
| 1 | 38 | 15 |
| 2 | 38 | 3 |
| 3 | 150 | 38 |
| 4 | 150 | 15 |
| 5 | 75 | 15 |
| 6 | 400 | 15 |
| 7 | 250 | 15 |
| 8 | 150 | 3 |
| 9 | 75 | 15 |
| 10 | 400 | 0 |
| 11 | 400 | 38 |
| 12 | 400 | 400 |
| 13 | 250 | 150 |
| 14 | 250 | 15 |
| 15 | 150 | 15 |
| 16 | 150 | 15 |
| 17 | 150 | 75 |
| 18 | 150 | 3 |
| 19 | 150 | 3 |
| 20 | 150 | 1 |

The investigations presented in this paper indicated clearly that parathion is a potentially effective chemical for the control of the green peach aphid. Carefully planned experiments are now under way in this tobacco district in which a number of insecticides will be carefully compared in a random block arrangement. Chemical analyses pertaining to surface residues and absorption of the chemical will be included. If safety factors are taken care of parathion will doubtless prove to be one of the key chemicals in the successful culture of shade-grown tobacco in northwest Florida and southern Georgia in 1948.—8-18-47.

## Dusts Containing Combinations of DDT, Sulphur, and Hydroxy Pentamethyl Flavan to Control Rat Ectoparasites[1]

HARVEY B. MORLAN,[2] *U. S. Public Health Service, Thomasville, Georgia*

Because of its effectiveness in controlling the oriental rat flea, *Xenopsylla cheopis* Rothschild, DDT is being used extensively at present in typhus control operations directed at rat ectoparasites. DDT dust, however, does not usually give marked control of the tropical rat mite, *Liponyssus bacoti* (Hirst), or the common rat louse, *Polyplax spinulosa* (Burmeister). Each of these species of ectoparasite has transmitted murine typhus fever experimentally among laboratory animals (Dyer, *et al.*, 1932; Dove & Shelmire, 1931; Mooser, *et al.*, 1931). It is desirable, therefore, to find substances which, when added to DDT dust and applied in typhus control operations, will control lice and mites. In connection with comprehensive typhus investigations being conducted by the Communicable Disease Center in south Georgia, two materials, hydroxy pentamethyl flavan[3] and sulphur, have been tested for this purpose.

Between August 1 and 7, 1946, rat runs and harborages on 15 rural premises in Cook County, Georgia where no insecticides had been used previously, were treated with three different dust mixtures with pyrophyllite as a diluent, namely, 10 per cent flavan and 8 per cent DDT, 50 per cent sulphur and 5 per cent DDT, and 10 per cent flavan. For purposes of comparing results, data were used from 5 premises that were not dusted as well as from simultaneous rat-trapping work in Brooks County, a more comprehensive typhus study area, where 10 per cent DDT dust alone was applied. From August 13 to October 23, 1946, 690 rats were examined for the presence of ectoparasites. Results indicated that the 10 per cent flavan dust alone, or when mixed with 8 per cent DDT dust, gave some control of mites and lice as did the sulphur-DDT dust mixture. Flavan used alone proved useless for flea control. Flavan with 8 per cent DDT gave better flea control than sulphur with 5 per cent DDT.

The foregoing results seemed to indicate the desirability of more extensive field tests with these materials, and three rural areas in the southern part of Cook County were selected for this work. Each of these areas contained from 50 to 75 rat-infested premises that had not been dusted previously. One area was used as a control area and was not dusted. Another area was dusted with a mixture of 8 per cent DDT and 10 per cent flavan between December 4 and 24, 1946, while a third area was dusted with a mixture of 8 per cent DDT and 10 per cent sulphur during the period, December 5 to 26, 1946.

Between December 17, 1946 and April 9, 1947, 845 rats were examined for ectoparasites. Results indicated that the sulphur-DDT dust combination gave slightly better control of the mite, *Liponyssus bacoti*, than did DDT dust alone, and that no ap-

[1] These studies were carried out in collaboration with the Georgia State Department of Public Health and the Cook County Commissioners.

[2] Dr. Elmer L. Hill and Mr. Jack E. Dent were associated with Mr. Morlan in the conduct of the work on which this paper is based.

[3] This material was supplied through the courtesy of E. I. du Pont de Nemours & Co.

preciable reduction in the abundance of this mite resulted from the addition of flavan to DDT dust. Neither of these substances gave significant control of *Polyplax spinulosa*. The addition of flavan or sulphur to DDT dust did not interfere with the efficiency of DDT in flea control.


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## Stem Borer Attacking Lilies


CHARLES F. DOUCETTE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*


The occurrence of stem borers in lily plants has been brought to the attention of the Sumner, Washington, field laboratory, of the Bureau of Entomology and Plant Quarantine, several times during the last few years. The first specimens were collected by Charles A. Cole, horticulturist of the Oregon Department of Agriculture, near Gold Beach, Oregon late in June 1942. Mr. Cole reported that he had observed this type of injury on lily plants in 1941. Specimens were also collected at San Francisco by Albert Vollmer in 1942. Adults reared from the larvae were determined by Carl Heinrich as *Emboloecia suzalitae papaipemoides* B. & B.

Since these initial collections, growers have sent in specimens, reporting injury to lilies in Coos and Lincoln counties, Oregon, and Clark and King counties, Washington. All specimens observed to date have been larvae in their last instar (Fig. 1). Whether the subspecies has food-plant habits similar to those of the species as reported by Lange (1939) is not known. As yet the infestations have not been extensive enough to be economically serious. However, the injury to lilies in localities extending from San Francisco, California, to the Puget Sound area in Washington indicates a possible preference for this host, and it may increase to serious numbers in the future.

FIG. 1.—Full-grown larva of *Emboloecia sauzalitae papaipemoides* B. & B. in lily stem.


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## Benzene Hexachloride to Control Certain Insects Affecting Domestic Animals[1]


H. S. TELFORD,[2] *Ashland, Ohio*


During the past 2 years the writer has conducted experiments with benzene hexachloride to control several arthropod pests attacking livestock and poultry. This report is a brief résumé of these observations. Data on cattle grubs are omitted, since these results were published elsewhere in the *Journal*.

Three species of chicken lice *i.e.*, body louse, *Eomenacanthus stramineus* (Nitzsch); shaft louse, *Menopon gallinae* (L.); fluff lice, *Goniocotes hologaster* Nitzsch, were prevalent in a coop containing 126 White Rock hens. A gallon of insecticide of 0.17 per cent gamma content, prepared from a wettable powder, was sprayed on the roosts and floor. Within 24 hours all shaft and fluff lice were controlled.

[1] "Paid Paper."
[2] Formerly Research Entomologist, Dr. Hess & Clark, Inc.

FIG. 1.—Sheep seriously infested with wool maggots.

**Table 1.—Summary of benzene hexachloride roost paints to control chicken lice.**

| FORMULATION | CC. PER LINEAL FOOT | DAYS OF OBSERVATION | DEGREE OF INFESTATION | BREED OF CHICKEN[1] | RESULTS OF TREATMENT |
|---|---|---|---|---|---|
| 1.55% gamma in *Ultrasene* | 1.5 | 7 | Moderate | W.L. | A few fluff lice dead within 24 hrs. Very poor control of all species. |
| | 2.6 | 7 | Moderate | B.O. | Very poor or no control. Poorly constructed roosts, very dirty. |
| | 3.0 | 30 | Moderate | B.O. | About 85% control. Owner said many of his birds were not roosting on roosts but on feeding troughs, nests, etc. |
| | 3.1 | 4 | Gross | B.R. | Complete control. |
| | 3.2 | 22 | Moderate | W.L. | Complete control within 22 days. One of 10 birds lightly infested after 4 days. |
| | 3.0 | 22 | Gross | W.L. | Complete ultimate control although a few were lightly infested after 4 days. |
| | 3.1 | 20 | Moderate | R.R. | Almost complete control within 4 days. Final complete control. |
| | 3.3 | 26 | Gross | B.R. | All free of lice within 4 days. |
| 1.27% gamma in No. 2 fuel oil | 3.2 | 4 | Gross | W.L. | Very little control within 24 hrs. One of 16 birds lightly infested within 4 days. |
| | 3.2 | 4 | Gross | W.L. | Very little control within 24 hrs. Complete control within 4 days. |
| | 3.2 | 4 | Moderate | W.L. | Complete control within 4 days. |
| | 3.8 | 4 | Moderate | W.L., W.R. | One of 10 birds examined, lightly infested. Remainder free of lice. |
| | 2.0 | 4 | Moderate | W.L. | One of 10 birds examined harbored a few lice. Remainder free of lice. |
| | 1.0 | 3 | Light | W.L. | All free of lice within 3 days. |
| | 1.0 | 5 | Moderate | W.L. | Three of 10 birds lightly infested within 3 days. All free of lice within 5 days |
| | 1.0 | 5 | Moderate to Gross | W.L. | Two of 10 birds lightly infested within 3 days. All free of lice within 5 days. |
| | 2.0 | 4 | Moderate to Gross | R.R. | All free of lice within 4 days |
| | 1.0 | 4 | Light[2] | B.R., W.L. | A few fluff lice remaining after 4 days. |
| | 2.0 | 4 | Light | W.L., R.R. | One of 10 birds lightly infested after 4 days. |
| | 1.2 | 3 | Moderate | R.R. | All free of lice within 3 days. |
| | 1.2 | 3 | Moderate | R.R. | All free of lice within 3 days. |

[1] W.L. = White Leghorn.
B.O. = Buff Orpington.
B.R. = Barred Rock.
R.R. = Rhode Island Red.
W.R. = White Rock.
[2] No body lice present; only fluff and shaft lice.

Within 5 days all species were eradicated. The birds, examined 3 months later were still free of lice. This formulation caused considerable nasal irritation to the operator and an objectionable odor remained in the hen house for 10 days or more.

To avoid the unpleasant odor and irritation, solutions of benzene hexachloride of 1.27 and 1.55 per cent gamma content were prepared, employing No. 2 fuel oil and *Ultrasene* respectively as solvents. These were applied on roosts with a small paint brush or oil can. Results of tests on 21 flocks, comprising approximately 3300 chickens infested with the above species of lice are shown in table 1.

It is believed that where satisfactory kills were not obtained, the chief cause was the chickens' failure to roost on the treated perches. In certain instances the roosts were in such poor repair that the birds would nor use them. Occasionally louse-infested brood hens would remain on the nests during treatment, thus being a source of infestation to the remainder of the flock. The material was easily applied. The solution penetrated quickly into the wood allowing no run-off. The birds showed no irritation. The odor was not pronounced.

Experiments were then undertaken to determine whether or not fuel oil solutions of benzene hexachloride of 1.27 per cent gamma content would taint eggs or poultry when applied at the rate of 1.5 cc. per lineal foot of roost. Two flocks of Rhode Island Red hens with approximately 50 birds in each group were employed. All hens were of the same age and maintained on identical rations. One flock was treated at 5:00 P.M. The other flock remained untreated as a control. Twelve hens in each flock were then killed and dressed. Six hens of each group were dry picked, while the remaining 6 were picked following a hot water treatment. The untreated birds were dressed first to avoid any possible contamination of benzene hexachloride from the workers, hands. The birds were then sold and the name of purchaser was secured at the time of sale. Every buyer was personally interviewed later regarding the palatability of the chickens. No unusual taste or odor was indicated.

**Table 2.—Effects of benzene hexachloride against certain pests of livestock and poultry.**

| Trial No. | Formulation | Host | Species of Parasite | Method of Treatment and Results |
|---|---|---|---|---|
| 1 | 5% tech.[1] on pyrophyllite | 3 heifers<br>2 cows | *Bovicola bovis* (Nitz.)<br>*Haematopinus eurysternus* Nitz. | Rubbed in by hand. All lice killed within 24 hours. |
| 2 | 2.5% tech.[1] on pyrophyllite | 5 heifers | *B. bovis* (Nitz.) | Rubbed in by hand. No mortality first half hour. Complete control within 24 hours. |
| 3 | 1.25% tech.[1] on pyrophyllite | 2 cows | *H. eurysternus* Nitz.<br>*B. bovis* (Nitz.) | Rubbed in by hand. Complete control within 24 hours. |
| 4 | 0.625% tech.[1] on pyrophyllite | 2 cows | *B. bovis* (Nitz.) | Rubbed in by hand. Complete control within 24 hours. |
| 5 | 0.375% gamma on pyrophyllite | 2 calves<br>cow | *Linognathus vituli* (Linné) | Rubbed in by hand. Complete control within 24 hours. |
| 6 | 1.0% gamma on pyrophyllite | 8 hogs | *Haematopinus adventicius* Neum. | All hogs grossly infested. Applied with a garden duster. Very irritating to operator. Complete control within 3 days. Lice population built up again within 3 weeks. |
| 7 | 1.25% tech.[1] on pyrophyllite | Sheep | *Melophagus ovinus* (Linné) | Keds treated in salve tins under dusting tower. All dead within an hour. |
| 8 | 0.625% tech.[1] on pyrophyllite | Sheep | *Melophagus ovinus* (Linné) | Same testing technique. All dead within 4 hours. |
| 9 | 0.12% gamma emulsion | Lamb | *Melophagus ovinus* (Linné) | Sprayed 8 ounces on animal. Light initial infestation. Within 24 hours only one live ked was recovered from animal. |
| 10 | 0.1% gamma suspension | Sheep | *Lucilia sericata* Meigen<br>*Phormia regina* Meigen | Wool badly fouled. Severe infestation over ¼ of posterior region of body. Five hundred cc. applied with sprayer. About 95% control within 24 hours. |
| 11 | 1.0% gamma suspension | Heifer[2] | *Demodex bovis* Stiles | Applied with stiff brush. No control. |
| 12 | 0.2% gamma formulated into a bar of soap. Ten grams of soap per liter of hot water. | Heifer | *Demodex bovis* Stiles | Applied with stiff brush. No control. |
| 13 | 0.2% gamma suspension | Heifer | *Demodex bovis* Stiles | Applied with stiff brush. No control. |
| 14 | Lanolin 81.0%<br>Water 9.5%<br>BHC (10%) tech. 9.5% | Cow | *Demodex bovis* Stiles | Pressed ointment into lesions with spatula. Almost complete control with 4 treatmentsat approximately 10-day intervals. |
| 15 | Lanolin 56.9%<br>Alcohol (isopropyl 98%) 22.1%<br>Water 14.5%<br>BHC (5%) wettable powder 6.3% | Cow | *Demodex bovis* Stiles | Pressed ointment into lesions with spatula. About 90% of lesions cured with 3 treatments at 10-day intervals. |
| 16 | Linseed oil 90.0%<br>BHC (10%) tech. 10.0% | Cow | *Demodex bovis* Stiles | Rubbed in by hand. Five treatments within a month cured about 80% of lesions. |
| 17 | Linseed oil 90.0%<br>BHC (10%) tech. 10.0% | Cow | *Demodex bovis* Stiles | Rubbed in by hand. Four treatments within 20 days cured almost all lesions. |
| 18 | 1.27 gamma in No. 2 fuel oil | Chickens | *Dermanyssus gallinae* (Deg.) | Sprayed on roosts and cracks in walls and ceilings of a moderately infested hen house. Apparently complete control within 3 days. |

[1] Gamma content unknown.
[2] In all treatments against *Demodex*, the lesions were first broken open by scraping the nodules thoroughly with a curry comb or blunt knife before applying the acaracide. The mites were demonstrated under the compound microscope from deep skin scrapings.

The egg tainting experiments were conducted as follows: The nests of both groups were closed to prevent chickens from entering the nests until 8:00 A.M. the following morning, at which time the nests were opened. At 12:00 o'clock noon, all eggs were collected and subjected to tests by blind-folding members of the writer's research staff, and allowing them to smell and taste (hard boiled) eggs from both the control and the treated flocks. No unusual odor or taste was perceived on either the treated or the control eggs.

That the above formulation does not taint eggs is further substantiated since in no case were there complaints from the 21 flocks owners or their clients when conducting the experiments recorded in table 1.

In addition to these experiments, trials were conducted against chewing and sucking lice and demodectic mange of cattle, the sheeptick, ked, or wool maggots, hog lice and chicken mites. A summary of these observations is shown in table 2.

RESULTS AND CONCLUSIONS.—1. Sprays composed of benzene hexachloride wettable powders at 0.17 per cent gamma content were efficacious against chicken lice, but were too irritating to the operator and too malodorous for practical use.

2. The odor was materially reduced when benzene hexachloride extracts of 1.27 to 1.55 per cent gamma

content were produced from No. 2 fuel oil or *Ultrasene*. Such formulations applied on roosts with an oil can or paint brush are generally effective against chicken lice when used at 1.0 to 3.3 cc. per lineal foot of roost space.

3. No evidence was secured indicating that benzene hexachloride fuel oil solutions of 1.27 per cent gamma content applied at 1.5 cc. per lineal foot of roost space tainted either eggs or dressed chickens.

4. Benzene hexachloride proved effective against sheepticks or keds, cattle lice, hog lice, chicken mites and wool maggots.

5. The compound shows considerable promise when employed in lanolin ointments or linseed oil solutions against demodectic mange of cattle. Water suspensions were less promising.—10-21-47.

## Effect of Flooding on Larvae of the Pecan Weevil in the Ground

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The possibility of controlling the pecan weevil *Curculio caryae* (Horn), by flooding the ground containing the larvae has been explored. In preliminary tests carried on at Brownwood, Texas, in 1943, 91 larvae removed from soil in the orchard on July 9 and placed in soil covered with water in a battery jar were dead on July 17.

The soil under a pecan tree (area 625 square feet) was flooded from August 2 to 12. Water 1 to 4 inches deep covered the higher portion of the plot 9 days and the lower portion 10 days. Air temperatures of 100° F. or higher occurred on all the days during the period in which the soil was flooded. The soil temperature 4 to 6 inches below the surface was 84° on August 12. Of 112 larvae removed from the flooded soil on August 16, 35 per cent were dead.

The same area was again flooded from August 17 to 27. Of 81 larvae taken from the flooded soil on August 31 and September 3, 43 per cent were dead. From an adjacent area not flooded 53 larvae were examined and only 4 per cent were dead.

These tests indicate that about one-third of the larvae in the ground may be killed by flooding for 10 days. This reduction is hardly enough to be of practical value.—8-3-47.

## Influence of Winter Night Temperatures on the California Red Scale

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Incidental to the compilation of data relating to the routine charting of orange orchards, which comprises much of the annual work of an Agricultural Inspector, the writer was able to obtain information relative to the influence of winter night temperatures on California red scale, *Aonidiella aurantii* (Mask.), populations during the years 1940, 1941, and 1942.

In the Covina Valley, California, it has been apparent for many years that red scale developed slowly, on both lemons and oranges, in areas of lower winter temperature, resulting in a comparatively light "carry over" of red scale through the winter and into the following spring. In areas of higher winter temperature, the red scale populations continued to increase perceptibly during the winter months, resulting in a heavy "carry over" of red scale into the spring months. It seemed reasonable to suppose that weather played an important part in red scale development and mortality.[1]

PROCEDURE.—To demonstrate the relationship of temperature to red scale population, the writer summarized the orchard charting records for the Covina Valley area for the three years mentioned above.[2] According to the orchard charting method of the Los Angeles County Department of Agriculture, red scale infestations are numerically graded according to a standardized system used by all the County Inspectors (Worthy & Wilcomb 1941). The higher the numerical rating for a particular orchard, the greater the average red scale population density in that orchard.

The Covina Valley was marked off in 50 foot contours on the regular United States Geological Survey quadrangle 5-foot contour maps. The red scale population density data relating to any one of the contours (400–450 feet, 450–500 feet, etc., above sea level) were averaged to obtain a single figure indicating the relative red scale population density in the orchards situated in the contour in question. The study involved 10 contour regions ranging in elevation above sea level from 350 to 850 feet.

The orchard charting (grading) operations started about the middle of June and continued through August, enabling pest control operators to obtain information concerning the orchards they planned to treat by the time the usual red scale control treatments were begun.

The weather records were obtained from the yearly reports of the United States Department of Commerce, Weather Bureau Fruit-Frost Service. The temperatures were obtained from thermometers placed at various elevations throughout the Valley. The number of nights the thermometer dropped to 32° F. and 28° F. in the various elevation strata was recorded.

Mr. Claude A. Cole, Associate Meteorologist of the Fruit-Frost Service of the United States Weather Bureau, made the following statement regarding elevation-temperature relationships in the Covina Valley:

> A graph showing the minimum temperature at different elevations shows the same consistent variations each winter season, *i.e.*, the lowest temperatures occur at the lowest elevations and with increasing elevation there is a gradual increase in the average minimum temperature. This is explained not only by the fact that cold air naturally gravitates to the lower elevations, but nocturnal drainage winds flowing out of the many canyons opening from the range of mountains bordering the north end of the valley tend to mix the cold surface air with warmer air aloft, resulting in higher temperatures over most of the upper valley. On the other hand, maximum daytime temperatures vary but little over the valley.

[1] Mr. A. F. Kirkpatrick has shown (unpublished data) that if both day and night temperatures are low, the red scale will become inactive and will live at very low temperatures with practically no mortality. The writer has observed, however, that high day temperatures in winter will result in growth and the development of young. If these warm days are followed by cold nights, a high mortality of young as well as scales in various other stages of development, will occur.

[2] The writer wishes gratefully to acknowledge the aid of students from the California Polytechnic School, San Dimas, California, who were responsible for the major part of the compilation of data in connection with an NYA project.

RESULTS.—The data obtained in this study of the relationship of temperature and elevation to red scale population density are shown in figure 1. In this figure are shown (1) the average number of nights the thermometer dropped to 32° F. and 28° F. at various elevation contours in the period November 15 to March 1 in 1940, 1941, and 1942, and (2) the relative red scale population densities at the various elevation contours also during these three years. The numerical values included in what is generally known as a "light," "medium," and a "heavy" infestation are also indicated in figure 1.

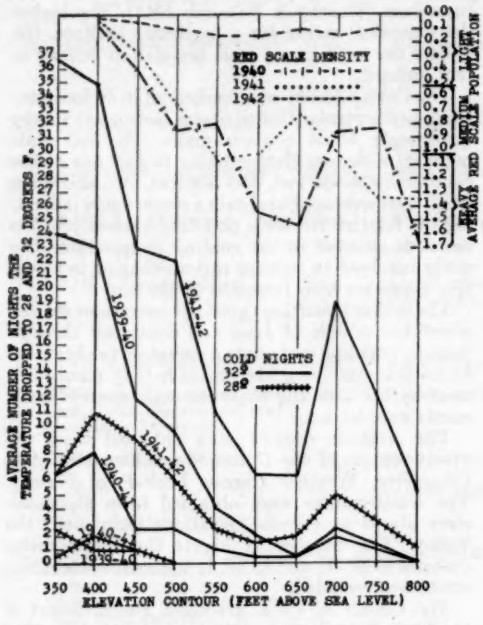


FIG. 1.—Relation of California Red Scale population density to winter temperature and elevation in the Covina Valley, California.

Figure 1 shows the general trend of fewer cold nights at the higher elevations and the general trend of higher red scale populations at these higher elevations. This is in accord with the investigations of Ebeling (1933) who found, within a hilly lemon orchard in the Yorba Linda district of Orange County, California, that red scale population density increased with increasing elevation within the orchard and the corresponding increase in night temperature. Ebeling also found that the day temperatures in this orchard were very similar at all elevations.

CONCLUSION.—From the data presented in figure 1, it can be concluded that red scale population density in the Covina Valley is inversely correlated with the number of nights during which the temperature dropped to 32° F. or lower in the period November 15 to March 1 during the 3-year period covered in this study. It is possible that the density of red scale populations in the following summer, within a given thermal belt, might be forecast on the basis of the number of cold nights during the winter in that particular belt.—7-25-47.

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## Efficacy of Certain Sprays in Control of Lice and Mites of Chickens[1]

J. E. ALICATA, L. KARTMAN, T. NISHIDA, and A. L. PALAFOX,[2] *University of Hawaii Agricultural Experiment Station, Honolulu*

Telford (1946) reported the effectiveness of DDT sprays in the control of chicken lice. He recommended the use of 1 pound of a 50 per cent wettable DDT powder to about 5 quarts of water. Telford & Guthrie (1946) also pointed out that a 2.5 per cent DDT spray was effective against the chicken mite, *Dermanyssus gallinae* (De Geer); this method however was said to require from 17 to 24 days before successful control could be realized.

Because of the apparent slowness of DDT spray against mites and conflicting reports on the efficacy of DDT dust on mites (Telford & Guthrie 1946), it was decided to conduct experiments to confirm the value of DDT spray under Hawaiian conditions and especially its effect on mites other than *Dermanyssus gallinae*. It was also decided to observe the effects of *Lethane*[3] sprays on both lice and mites and on the value of combining *Lethane* and DDT against these two groups of ectoparasites. The effectiveness of "*Lethane A-70*"[3] in the control of lice and mites when applied as a dust on individual birds has already been reported by Alicata, *et al.*, (1946). These authors also recorded on 85 per cent reduction of body mites, *Megninia cubitalis*, 48 hours following the application of 5 per cent DDT dust to the birds.

In the present study the chickens were sprayed with an aqueous suspension of 50 per cent DDT,[4] *Lethane B-72*,[3] and a mixture of the two. The birds were sprayed as a flock and in individual laying batteries. The spray was applied gently over the birds with the aid of a compressed-air type of garden sprayer. To prevent clogging, a spray disc with an aperture of 1 mm. was used in the nozzle. Each bird received, on the average, about 28 cc. of the diluted spray. The ectoparasites found on these birds included the following: Lice, *Eomenacanthus stramineus* (Nitzsch), *Goniocotes gallinae* (De Geer), *G. gigas* Taschenberg, *Lipeurus caponis* (Linn.), *Menopon gallinae* (Linn.); Mites, *Megninia cubitalis* (Megnin).

The method of estimating the louse and mite population on each bird was the same as that reported by Alicata *et al.* (1946). It consisted of rating

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[3] Manufactured by Rohm and Haas, Philadelphia.

[4] *NB-50*. Manufactured by Pennsylvania Salt Mfg. Co., Philadelphia.

**Table 1.—Average of louse and mite infestation on chickens before and after spraying with aqueous suspensions of DDT, *Lethane B-72*, and DDT-*Lethane B-72:* (a) before; (b) 1 week after; (c) 1 month after.**

| Exp. No. | Insecticide | Number of Birds Kept as a Flock (f) or in Individual Laying Batteries (b) | Body Lice | | | Body Mites | | |
|---|---|---|---|---|---|---|---|---|
| | | | (a) | (b) | (c) | (a) | (b) | (c) |
| 1 | DDT[1] | 40 (f) | 5.0 | 0.0 | 0.0 | — | — | — |
| 2 | DDT[1] | 22 (f) | 5.0 | occasional | 0.0 | — | — | — |
| 3 | DDT[1] | 40 (f) | 5.0 | 0.0 | 0.0 | — | — | — |
| 4 | DDT[1] | 13 (f) | — | — | — | 49.5 | 10.7 | 21.9 |
| 5 | DDT[1] | 9 (b) | — | — | — | 4.0 | 0.8 | 0.3 |
| 6 | DDT[1] | 48 (f) | — | — | — | 6.3 | 0.2 | 0.0 |
| 7 | Lethane[2] | 10 (f) | — | — | — | 44.2 | 0.0 | 0.0 |
| 8 | Lethane[2] | 9 (f) | — | — | — | 5.2 | 0.0 | 0.0 |
| 9 | Lethane[2] | 50 (f) | 4.0 | 3.0 | 4.0 | — | — | — |
| 10 | Lethane[2] | 24 (b) | 5.0 | 0.0 | 0.0 | — | — | — |
| 11 | DDT-Lethane[3] | 30 (f) | 5.0 | 0.0 | 0.0 | — | — | — |
| 12 | DDT-Lethane[3] | 28 (f) | 4.0 | 0.0 | 0.0 | 5 per feather | 0.0 | 0.0 |
| 13 | DDT-Lethane[3] | 52 (b) | — | — | — | 40.0 | 0.0 | 0.0 |
| 14 | DDT-Lethane[4] | 52 (b) | 4.0 | 0.0 | 0.0 | 10.0 | 0.0 | 0.0 |
| 15 | DDT-Lethane[4] | 78 (b) | — | — | — | 4 per feather | 0.0 | 0.0 |
| 16 | DDT-Lethane[4] | 16 (b) | 5.0 | 0.0 | 0.0 | — | — | — |

[1] 1 pound of 50 per cent wettable DDT in 5 quarts of water.
[2] 6.5 ounces of *Lethane B-72* in 1 quart of water.
[3] 1 pound of 50 per cent wettable DDT mixed with 12 ounces *Lethane B-72* in 6 quarts of water.
[4] 1 pound of 50 per cent wettable DDT mixed with 8 ounces *Lethane B-72* in 6 quarts of water.

the degree of infestation by assigning numerical values as follows: 0, none; 1, 1 to 10 lice on entire body; 2, approximately 10 to 100 lice on body; 3; 1 to 2 lice per square inch of body surface (s.i.b.s.), 4, 3 to 5 lice per s.i.b.s.; 5, 6 or more lice per s.i.b.s. In estimating the body mite population, counts were made of the number of mites collected by suction from an area of about 2 square inches of the dorsal portion of each bird. In a few instances the average was taken on the number of mites found on four body feathers plucked at random.

The results obtained in the present study, which are summarized in table 1, show that DDT spray applied at the rate of 1 pound (50 per cent wettable DDT) to 5 quarts of water resulted in an effective control of lice (Experiments 1, 2, and 3), and partial to complete control of mites (Experiments 4, 5, and 6). Birds in Experiments 1 to 3 were found free of lice when last examined 2 months after spraying. Sprays with *Lethane B-72*, applied at the rate of $\frac{2}{3}$ pound to 1 quart of water, gave complete control for mites (Experiments 7 and 8) and partial to complete control for lice (Experiments 9 and 10). The combination of the above two insecticides at the rate of 1 pound of 50 per cent DDT and $\frac{3}{4}$ or $\frac{1}{2}$ pound *Lethane B-72* in 6 quarts of water resulted in the complete control of both lice and mites within a period of 1 week (Experiments 11 to 15). It is also desirable to mention that untreated chickens kept in pens adjoining those which were treated remained infested with lice and mites.

The above results point out that a 50 per cent wettable DDT spray was more consistent in completely controlling lice than mites. Lethane B-72 spray, on the other hand, appeared to be more effective in controlling mites than lice. When DDT and Lethane were combined, the results were in all cases consistent in the complete destruction of both lice and mites as regards immediate and residual kill.

Since chickens commonly harbor both groups of ectoparasites simultaneously, it is concluded that this combination of insecticides should offer a better and simpler means of control than the usual individual application of dusts or dips. This has been borne out by the use of the DDT-*Lethane* spray in Hawaii by commercial poultrymen.

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## Some Insecticides Causing Boll Weevil Mortality Inside of Punctured Cotton Squares[1]

C. F. Rainwater, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In the course of field experiments with several insecticides for control of the boll weevil, *Anthonomus grandis* Boh., during the summer of 1947, it became evident that something unusual was happening in certain plots which was keeping the infestation at a low level. One possibility was the ovicidal or larvi-

[1] Paid Paper.

cidal action was being shown by certain of the insecticides. Large numbers of fruiting buds, or squares, in which eggs had been deposited, and which had dropped from the plants, were therefore collected from dusted plots, held in cages until emergence of weevils was apparently complete, and then examined to find out what had happened to the weevils developing therein.

The first series of tests was made on 200 punctured squares collected from six plots that had received five applications of insecticidal dust. Each plot was dusted with a different insecticide. Collection was made on July 22, 8 hours after the fifth application. The punctured squares were placed in screen-wire cages (18 by 24 by 3 inches) which were kept in a darkened enclosure. From each cage four large vials protruded through the enclosure into the light, and the emerging weevils were attracted into these vials by phototropic response. Emergence began on July 31 and continued until August 6. The insecticides tested and the total numbers of weevils to emerge from the squares are given below. The strengths indicated were obtained by adding a dust diluent to the technical product.

| Insecticide | Weevils |
|---|---|
| Calcium arsenate | 102 |
| Gamma-benzene hexachloride 6% | 12 |
| Gamma-benzene hexachloride 3% plus DDT 5% | 42 |
| Chlorinated camphene 20% | 83 |
| Chlordane 20% | 0 |
| 0,0-Diethyl 0-*p*-nitrophenyl thiophosphate 2% | 117 |

Since no weevils emerged from the squares collected from plots treated with 20 per cent chlordane dust, these squares were examined to determine the reason. Development within the squares was apparently normal to the adult stage, but the adults were dead or were paralyzed and unable to emerge. There were 49 live adult boll weevils which were unable to stand or crawl but were able to move their feet slowly when lying on their backs. In addition, 42 dead adults were found inside the squares.

Unfortunately, the squares from the other cages were destroyed before they were examined, and no data other than actual emergence is available from them.

During the remainder of the season eight other series of punctured squares were collected from plots treated with the same insecticides at different strengths and caged in a similar manner. The time of collection in each series is given below.

| Series | Application | Hours after indicated application |
|---|---|---|
| 1 | Fifth | 8 |
| 2 | Second | 56 |
| 3 | Seventh | 32 |
| 4 | Ninth | 50 |
| 5 | Ninth | 56 |
| 6 | Ninth | 100 |
| 7 | Third | 52 |
| 8 | Third | 100 |
| 9 | Seventh | 172 |

Toward the end of the season it was not always possible to find 200 punctured squares from each plot. Moreover, the supply of screen-wire cages of the type described above was limited, and so the squares for the last four series were placed in avail-

**Table 1.—Per cent mortality of boll weevils in cotton squares collected from plots treated with different insecticides.**

| Insecticide | Series | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Calcium arsenate | | — | — | — | — | — | 4 | — | 4 | 52[1] | 20 |
| γ-benzene hexachloride | | | | | | | | | | | |
| 6% | | — | — | — | 36 | 37 | 81 | — | — | — | 53 |
| 5% | | — | 77 | — | — | — | — | 95 | 55 | — | 76 |
| 3% | | — | — | — | 8 | 34 | 31 | — | — | — | 24 |
| 1% | | — | — | — | — | — | 22 | — | 29 | — | 26 |
| DDT 5%+γ benzene hexachloride | | | | | | | | | | | |
| 3% | | — | 49[2] | 59 | 24 | 42 | 58 | 57[2] | 70[2] | 46[2] | 50 |
| 2% | | — | — | — | — | — | 67 | — | — | — | 67 |
| 1% | | — | — | — | — | — | 29 | 46 | — | — | 38 |
| DDT 50% (alternate applications only) | | — | — | — | — | — | 21[3] | — | — | 3 | 12 |
| Chlorinated camphene | | | | | | | | | | | |
| 20% | | — | — | — | 35 | 35 | 39 | — | — | 33 | 36 |
| 10% | | — | 10 | — | — | — | — | 9 | 19 | 29 | 16 |
| 0,0-Diethyl 0-*p*-nitrophenyl thiosphosphate | | | | | | | | | | | |
| 5% | | — | 5 | — | — | — | — | — | 2 | — | 2 |
| 5% | | — | — | — | — | — | 19 | — | — | — | 19 |
| 1% | | — | — | — | — | — | — | — | — | 52[1] | 52 |
| 2%+DDT 2% | | — | — | — | — | — | — | — | 2 | — | 2 |
| Chlordane | | | | | | | | | | | |
| 20% | | 100 | — | 98 | 85 | 76 | 95 | — | — | 100 | 92 |
| 10% | | — | 82 | 95 | — | — | — | 95 | 66 | 83 | 84 |
| 10%+DDT 5% | | — | — | 96 | — | — | — | 95 | 89 | 71 | 88 |
| 5%+DDT 5% | | — | 84 | 84 | — | — | — | — | — | 79 | 82 |
| 5%+chlorinated camphene 5% | | — | — | — | — | — | — | — | — | 75 | 75 |
| Check (untreated) | | — | — | 5 | 4 | 6 | 7 | — | 1 | 12 | 5 |

[1] The squares were badly molded in these cages when checked out and the emergence was below normal.
[2] Severe burning of the cotton foliage.
[3] 8 days after the last application.

able wooden cages (5 by 5 by 5.5 inches and 6 by 8 by 8 inches) constructed from 1-inch boards. Only one glass vial protruded from each cage. Some of the squares in these cages molded badly, a fact which perhaps influenced the emergence.

Daily records were made for all cages, and after emergence was complete every square was carefully examined. Records were kept of emerging adult weevils, live and dead adults in squares (for the purpose of these tests all adults in squares at time of checking out were regarded as dead), dead pupae and larvae in squares, and dead adults on bottom of cage. However, since it was impossible to determine whether mortality in the larval and pupal stages was from natural causes or from insecticidal effect, and since there was comparatively little mortality in these stages, it was decided to omit these records in computing mortalities due to insecticidal effect.

Table 1 is a summary of results of tests with all nine series of caged squares.

It should be stressed that the mortalities shown in table 1 resulted from normal applications of the various insecticides for the control of the boll weevil under actual field conditions. The interval between the time of application and the time the squares were collected apparently had little or no effect on the mortality.

In general, these studies indicate comparatively little mortality of boll weevils developing within punctured squares when calcium arsenate, 50 per cent DDT, or 1 to 5 per cent of 0,0-diethyl 0-*p*-nitrophenyl thiophosphate was applied to cotton in the field. In the plot treated with 20 per cent chlorinated camphene the average mortality was 36 per cent, which indicates some toxicity, and in that treated with 10 per cent chlorinated camphene 16 per cent, which is not appreciable.

The benzene hexachloride and the mixture of benzene hexachloride and DDT were from two sources and gave wide differences in mortality. A product containing 5 per cent of the gamma isomer caused a much higher mortality than one from another source containing 6 per cent of the gamma isomer. Likewise a commercial product containing 5 per cent of DDT and 3 per cent of gamma-benzene hexachloride caused a higher mortality than a similar mixture prepared in the laboratory from 6 per cent of the gamma isomer and 50 per cent of DDT. Such extremes were also noted in other characteristics of the two products. The one causing the greater mortality also caused severe burning of cotton foliage, had a much more pungent irritating odor, and was considerably heavier than the other.

Benzene hexachloride, however, caused appreciable mortality of boll weevils developing within punctured cotton squares.

Mortalities from mixtures of DDT and of gamma-benzene hexachloride were variable, although perhaps there were not enough trials for the mixtures containing 1 and 2 per cent of gamma isomer.

Chlordane was the most effective insecticide tested against boll weevils within punctured squares.

The discovery that some of these new organic insecticides are highly effective against boll weevils developing within punctured squares is of tremendous potential economic value. The entire concept of boll weevil control could be changed as a result of these findings. In addition to the economic aspects involved, a new field of investigation has been opened which might well result in findings of much greater economic importance than those reported herein.—11-29-47.

## Winter Control of *Anopheles freeborni*

R. G. ROSENSTIEL[1]

The chemical dichloro-diphenyl-trichlorethane (DDT) was used in buildings near the Merced, California, Army Air Field during the winter of 1944–45 and near Dixon, California, in 1946 in order to ascertain its effects on overwintering female mosquitoes of the species *Anopheles freeborni* Aitken. The populations of the mosquitoes were low at the time of the experiments and the sluggish females were present only in dark corners of structures which protected them from wind and rain.

Freeborn (1932) speaking of *Anopheles freeborni* states that " . . . no true hibernation occurs, the overwintering females biting frequently on warm days or in heated buildings and changing their resting places frequently throughout the winter." Naumov (1941) worked with *Anopheles maculipennis* var. *messeae*, Fini. in Russia. He examined 119 thousand potential anopheline resting places and was able to control hibernating adults which reduced the incidence of malaria. Theoretically, a complete kill of *A. freeborni* in California during the winter should eliminate danger of a malaria epidemic in the vicinity during the following season.

Forty-two farms having maximum *Anopheles freeborni* populations were selected for chemical treatment in the Merced study. Each treatment was applied to a group of seven adjacent farms. All of the buildings treated had unpainted wooden walls. Each of the test chemicals listed in table 1 was used on the interior of 9 to 13 mosquito natural resting places[2] while the untreated population was sampled in 22 resting places. It was never possible to treat all the buildings on a farm, and the houses were not sprayed. The Merced experiment lasted from December 22, 1944, when the chemicals were applied, until the end of February, 1945. Table 1 lists the chemicals used and their effects on the female anophelines 5 and 8 weeks after the spray application. The dosage in milligrams of DDT per square foot was based on the amount of spray used. The effectiveness of the chemicals was based on the average of the *A. freeborni* female population found before and after treatment.

The 98 per cent DDT was dissolved in No. 2 diesel oil and used in the undiluted oil. The two commercial DDT products contained organic wetting agents and a DDT solvent. They were emulsified in water and used with one per cent summer oil. The 20 per cent DDT was in wettable dust form. The summer oil and diesel oil were used separately as standard treatments for comparison with DDT combination treatments.

Application was by means of a 50 gallon capacity, orchard-type spray outfit mounted on a half-ton truck. The spray was delivered at 350 pounds pressure through a sixteenth-inch orifice in the spray gun. The rate of spray application was enough to visibly wet smooth, unpainted, wooden walls but was not enough to cause run-off.

The 5 per cent DDT concentration gave perfect control throughout the test period. The two commercial preparations gave 88 to 100 per cent control for 8 weeks. The effect of diesel oil alone appears to merit further study. The average untreated resting places population was constant through late Decem-

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[2] Called merely "resting places" in further discussions.

Table 1.—DDT sprays applied to *Anopheles freeborni*, Merced, California, 1944–45.

| Chemical | Concentration in Spray | Gal. Used per 1,000 Sq. Ft. | Mg. DDT per Sq. Ft. | Per Cent Control | |
|---|---|---|---|---|---|
| | | | | 5 Wks. | 8 Wks. |
| 98% DDT | 5% | 1.03 | 161 | 100 | 100 |
| 20% DDT Dust[1] | 0.03% | 1.03 | 1.16 | 97.1 | 88 |
| 13% DDT Liquid[1] | 0.03% | 0.88 | 0.99 | 98.8 | 100 |
| Oil[1] (Summer)[2] | 1% | 1.10 | — | 0 | 0 |
| Diesel Oil #2 | 100% | 1.21 | — | 90.9 | 92 |
| Untreated | — | 0.0 | — | 0 | 0 |

[1] These materials were furnished by California Spray-Chemical Corporation, Richmond, California.
[2] This petroleum oil emulsion was light medium, UR 94, manufacturer's specification.

ber and all of January, but decreased rapidly from 47 after 5 weeks (February 1) to 5 after 8 weeks (February 25). This natural decrease, which was due to the habits of the treated species, precluded carryong on the test for a longer time.

DDT at concentrations of 5 and 0.03 per cent gave excellent winter kills in the above test over a 5-week period when sprayed directly on *Anopheles freeborni* females in December.

The chemical DDT was used as an aerosol in a carrier of "fog like" water droplets in the vicinity of Dixon, California, on January 10, 1946, as a quick killing insecticide on overwintering female mosquitoes of the species *Anopheles freeborni*.

Three different unpainted wooden anopheline resting places were treated with each DDT dilution and three were left untreated for comparison. Only one resting place received the water "fog" treatment alone. The applicator was a preliminary model aerosol generator[3] consisting of a coiled water heater for stream production and a pump which delivered the insecticide to the end of the delivery nozzle where it joined the emerging steam. The steam borne spray was carried for 30 to 40 feet away from the nozzle in an aerosol. The aerosol was cool as close as 3 feet from the generator even though the steam emerged at 550° F. at the rate of approximately 900 miles per hour. The machine was calibrated to deliver 0.67 gallon of equal amounts of steam and emulsified insecticide per minute at the above temperature. Dosages were measured by calculating the surface area to be treated and then timing the application with a stop watch.

All the population counts of table 2 are averages of 3 replicates except for the "water only" treatment which was applied at one location. Treated population averages were compared to the first counts in computing per cent control.

Table 2.—The effect of DDT in an aerosol on *Anopheles freeborni* females in January.

| DDT Per Cent Concentrate | Av. Mg. DDT per Cu. Ft. | A. *Freeborni* Female Population | | | Per Cent Control |
|---|---|---|---|---|---|
| | | Before | 1 day | 7 days | |
| 0.001 | 1.4 | 104 | 0 | 5 | 95.3 |
| 0.01 | 12.3 | 50 | 1 | 3 | 94.0 |
| 0.1 | 100.9 | 151 | 1 | 0 | 100.0 |
| Water only | 0.0 | 60 | 70 | 76 | 0.0 |
| No treatment | 0.0 | 84 | 85 | 86 | 0.0 |

Table 2 shows that the application of a "fog" of water alone had no adverse effects on *Anopheles freeborni* females. The DDT was highly insecticidal in an aerosol at dilutions as low as 1 part in a thousand when applied to torpid female *A. freeborni* mosquitoes.

[3] Manufactured by Bessler Corporation, Emeryville, California.

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## DDT Dust Deposits on Pears

A. D. Borden,[1] *University of California, Berkeley*

The use of DDT (dichloro-diphenyl-trichloroethane) in dusts and concentrated sprays offers a most promising means of controlling codling moth on pears and apples. By these methods the cost of labor and materials may be greatly reduced providing adequate equipment is available and correct formulations and dosages of the materials are employed. In dust applications the proper formulation of the dust material so as to improve deposit and retention of the dust on the fruit is important. Very little data on field experimentation are available and for that reason the following preliminary field test was conducted this season (1947).

The experimental plot was in a 35 year old Bartlett pear orchard of uniform sized trees which had an abundance of foliage. This orchard had received a delayed calyx spray of 2 pounds of 50 per cent wettable DDT per 100 gallons on April 4 at an average dosage of 15 gallons of spray solution per tree applied by a speed sprayer. A 22 acre area near the center of the orchard was divided into eight plots (each plot 12 tree rows wide by 21 trees long) giving an acreage of from 2.4 to 3 acres per plot. The four plots on the east side were dusted at a dosage of 50 pounds per acre with the four formulations selected for the test. The four plots on the west were to receive a dosage of 100 pounds per acre of the same materials. In the actual applications the dosage on the four plots to the east was fairly accurate in both applications, but the dosage on the four plots to the west was nearer 75 pounds per acre in the first application and 100 pounds per acre in the second.

[1] P. S. Messenger cooperated in the work.

**Table 1.—Average amount of DDT on pears receiving 50 pounds DDT dust per acre.**

| Dust Mixture | DDT—p.p.m. After First Application | DDT—p.p.m. Before Second Application | Percentage Retention | DDT—p.p.m. After Second Application | DDT—p.p.m. At Harvest | Percentage Retention |
|---|---|---|---|---|---|---|
| A | 13.7 | 5.6 | 40.8 | 7.4 | 0.9 | 12.1 |
| B | 15.5 | 6.4 | 41.3 | 7.9 | 11. | 14.0 |
| C | 19.1 | 5.3 | 27.7 | 9.2 | 0.7 | 7.6 |
| D | 22.7 | 4.4 | 19.4 | 7.9 | 0.35 | 4.4 |

**Table 2.—Average amount of DDT on pears receiving 75 to 100 pounds per acre.**

| Dust Mixture | DDT—p.p.m. After First Application | DDT—p.p.m. Before Second Application | Percentage Retention | DDT—p.p.m. After Second Application | DDT—p.p.m. At Harvest | Percentage Retention |
|---|---|---|---|---|---|---|
| A | 14.5 | 6.4 | 44.1 | 8.0 | 0.8 | 10.0 |
| B | 17.8 | 7.0 | 39.3 | 13.2 | 2.3 | 17.3 |
| C | 25.0 | 7.2 | 28.8 | 13.2 | 0.7 | 5.3 |
| D | 24.2 | 5.4 | 22.3 | 11.4 | 0.5 | 4.4 |

The equipment used was a No. 5 *Masterfan* type of duster with two wide fishtail discharge vents and it was drawn by a tractor. The speed of the equipment and the hopper openings were regulated so as to apply the proper amount of material to each plot.

The dust materials (*) employed were primarily 10 per cent technical DDT in pyrophyllite with and without adhesives added. The adhesives employed in the dust mixtures were as follows: Dust A—4 per cent fatty acid derivative; Dust B—4 per cent Vacatone; Dust C—2 per cent light-medium grade spray oil; Dust D—no adhesive.

The applications were made at night on April 22 and May 8. Atmospheric conditions were very favorable for dusting though somewhat low in humidity. During the period from April 22 to July 1, the date of final sampling, the rainfall records were: May 27—.10, June 7—.45 and June 9—.31 inches.

Sampling of the fruit before and after each application and at harvest was made by collecting 50 random samples of fruit from each plot in clean glass jars with lids, and these were brought into the laboratory for analysis. Residues were removed from each 25 fruit at time of first application, at least one half kilogram of fruit at time of the second application and about one kilogram at harvest using benzene as stripping agent. Chemical analysis of the strippage was by the total dehalogenation method using metallic sodium in absolute alcohol solvent; chloride so obtained being determined by *Volhard* titrations involving silver nitrate and potassium thiocyanate. This method is not specific for DDT but in view of the fact that the control schedule was known with certainty, this is of no moment. Further the method gives fives times the accuracy over the monochloride scheme of analysis for DDT.

The data obtained from the analysis showed that though the initial deposits were higher in the formulations containing no adhesive and two per cent oil the retention of deposits was definitely better in both periods of sampling when adhesvies A and B were employed in the formulations.

No significant advantage was apparently gained by the higher dosage (75–100 pounds per acre) over the 50 pound dosage.

The build up of deposit in the second application was much lower than normally would be expected, but it is in line with arsenical deposit studies on pears in which late applications showed a lower build up of deposit.

A random sampling of 500 fruit from each of the plots at harvest showed but two codling moth worm entries in 4000 fruit inspected.—7-27-47.

## Benzene Hexachloride, DDT, and *Ryanex* to Control Soybean Caterpillars

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For the past several years, soybean caterpillars have been responsible for the complete failure of numerous soybean crops in eastern North Carolina. This has been especially true in Hyde County where the destruction wrought by various species of caterpillars reaches a peak about the first 2 weeks in September. Most of this damage can be prevented by one timely application of a suitable insecticide.

In the fall of 1946 a series of tests were planned for the purpose of checking on the effectiveness of different concentrations of benzene hexachloride, DDT, and *Ryanex* for the control of the various species of soybean caterpillars. Another test was planned to check on the effectiveness of an early application of 5 per cent DDT dust compared to a late application.

MATERIALS USED.—In the first test, two types of 5 per cent DDT dust[2] were used—one a straight-grind dust and the other a micronized dust reported to be of finer particle size than the straight-grind material. The benzene hexachloride dusts used were 1, 2, 5, and 10 per cent concentrations of the gamma isomer.[3] *Ryanex*,[4] a plant-product insecticide, was used at the 50 per cent concentration.

PROCEDURE.—The dusts were applied with a rotary-type hand duster at about 25 pounds to the acre. Plots were 50 feet long and 5 rows wide. Rows were planted 42 inches apart. There was a buffer zone of two untreated rows between the plots. Each treatment was replicated four times. A single application of dust was made on all treated plots on September 12. The area of the plots was examined before treatment and a count made of soybean caterpillars. Additional caterpillar counts were made 4 hours after treatment and again 5 days after treatment. A sample caterpillar count consisted of counting the number of larvae on 6 plants from each plot. The plants were shaken over a plain piece of paper thus dislodging the larvae and facilitating finding and counting them.

The materials used in the first test and the results of the sample caterpillar counts are listed in table 1. The bean variety used in the test was the *Arksay*.

In the second test, 5 per cent straight-grind DDT dust was used on two different days on two plots of beans consisting of 200 feet of row. One plot was dusted on September 9 and the plot adjacent to it was dusted 3 days later. Each of these plots received only one dusting at about 25 pounds of 5 per cent

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[2] Supplied by the Maxwell Insecticide Co., Raleigh, N. C.
[3] Supplied by the Penn. Salt Mfg. Co., Philadelphia, Pa.
[4] Supplied by Merck and Co., Rahway, N. J.

DDT per acre. The variety used in this test was the *Tokio*.

RESULTS.—The yield data listed in table 1 shows that all lf the treated plots gave a much higher yield than did the untreated checks. Upon statistical analysis it was determined that there was a significant difference between the treated plots and the untreated checks. However, no significant difference could be shown between the various insecticidal treatments as used in the first test. Plots treated with benzene hexachloride, 5 and 10 per cent dusts, had fewer larvae than any other treated plots in each of the 2 post-treatment counts and these plots also had the highest yield of the treated plots. The highest number of larvae recorded in the post-treatment examinations of the treated plots was in the *Ryanex* plots and the lowest yield from any of the treatments was also recorded in these plots. In general, the untreated check plots had about half the yield of the treated plots.

**Table 1.—Materials used, number of caterpillars in 2 post-treatment counts, and yields obtained in 1946 tests for soybean caterpillar control.**

| Treatment | Number of Caterpillars | | Yield—Bushels per Acre |
|---|---|---|---|
| | 4 Hours After Treatment | 5 Days After Treatment | |
| Straight-grind 5% DDT dust | 13 | 2 | 11.9 |
| Micronized 5% DDT dust | 28 | 4 | 12.6 |
| Benzene hexachloride, 1% dust | 32 | 0 | 12.1 |
| Benzene hexachloride, 2% dust | 13 | 2 | 12.0 |
| Benzene hexachloride, 5% dust | 7 | 0 | 13.2 |
| Benzene hexachloride, 10% dust | 9 | 0 | 12.9 |
| *Ryanex*, 50% dust | 28 | 30 | 10.3 |
| Untreated check | 112 | 28 | 6.4 |

[1] Total for 24 plants, 6 in each of 4 replicates. Pretreatment count in area of plots averaged 102 caterpillars on 24 plants.

In the second test, the yield from the earlier treated plot of September 9 was 28.0 bushels per acre whereas the yield from the plot treated 3 days later, on September 12, was 18.6 bushels per acre—a reduction of nearly 34 per cent.[5]

DISCUSSION.—The principal insects observed to be attacking soybeans in Hyde County, N. C. during September 1946 were the velvetbean caterpillar,[6] and the corn earworm. Other caterpillars commonly found in soybean fields at this time were the yellow-striped armyworm, the fall armyworm, and species of the *Autographa* group.

The chief damage done to soybeans by these pests was caused by their feeding on the foliage. The velvetbean caterpillar is a ravenous feeder and the results of its feeding were evident in many fields in Hyde County in the early part of last September. A characteristic type of injury is caused by the corn earworm which feeds on the seed pods of the beans. In periods of heavy infestation, the leaf feeders will strip the plant of its foliage and the corn earworm will ruin the seed by feeding on and within the pods.

When both of these pests attack a field of beans, immediate action is necessary if the crop is to be saved. The timely application of quick-acting insecticides can save a field and in most instances only one application is necessary. Cryolite has given fair control of the leaf feeders and of the corn earworm. Five per cent DDT has been reported giving as good or better control of the corn earworm and better control of the leaf feeders (Smith 1946). Growers prefer DDT dust because it is quicker acting than cryolite.

A material of high residual quality such as DDT cannot be recommended for use on soybeans in cases where the dust is to be applied late in the season and where the foliage is to be used for feed. In such cases, use of benzene hexachloride may be advisable. At this writing, it is not known whether benzene hexachloride flavors the foliage of soybeans or not. The beans used in the tests reported herein were used for seed and no attempt was made to determine the quality of the foliage when used as hay or the effects of insecticidal residue when treated foliage was used as feed.

SUMMARY.—The principal insects attacking soybeans in eastern North Carolina are the velvetbean caterpillar *Anticarsia gemmatilis* Hbn., and the corn earworm, *Heliothis armigera* (Hbn.). The former feeds on soybean foliage and the latter attacks the pods. Other caterpillars commonly found attacking soybeans in this area are the yellow-striped armyworm, *Prodenia ornithogalli* Guenee, and the fall armyworm, *Laphygma frugiperda* S. and A., and species of the *Autographa* group.

No significant difference in yield was noted between any of the following treatments: benzene hexachloride dusts of 1, 2, 5, and 10 per cent gamma isomer content, DDT 5 per cent straight-grind dust, DDT 5 per cent micronized dust, and *Ryanex* 50 per cent dust. All plots received only 1 application of dust. A significant difference in yield was noted between all dust treatments and the untreated checks.

In two different plots of beans in the same field, beans treated with 5 per cent DDT dust on September 9 yielded nearly 34 per cent more than beans treated 3 days later, on September 12.—7-11-47.

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[5] Data for this second test supplied by J. P. Woodard, County Agent, Hyde County, Swan Quarter ,N. C.

[6] Caterpillar determinations made by Mr. C. Heinrich of the U.S.N.M., Washington, D. C.

## Insecticides for Cattle Grub Control

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During the past year the writer investigated new and old insecticides for the control of cattle grubs. The following is a brief summary on these observations.

METHODS AND MATERIALS.—All animals were from Ashland County, Ohio. Both *Hypoderma lineatum* (De Vill.) and *H. bovis* (Deg.) were involved. The latter species greatly predominated. A record of each treated warble was maintained by marking its location on a diagrammatic drawing of the animal's back. All subjects were treated once. They were examined about 5 to 7 days after treatment and one or two subsequent examinations were made at approximately weekly intervals.

The insecticides were formulated as (1) dusts, (2) solutions of linseed oil and (3) lanolin ointments. The dusts were applied with a salt-shaker type applicator over the entire back of the animal and rubbed in thoroughly by hand. The particle size of

**Table 1.—Summary of cattle grub experiments.**

| TRIAL NO. | FORMULA | PER CENT BY WEIGHT | ANIMALS TREATED | GRUBS TREATED | GRUBS KILLED | GRUBS SURVIVED | PER CENT MORTALITY | METHOD OF APPLICATION |
|---|---|---|---|---|---|---|---|---|
| 1 | Lanolin<br>*Toxaphene*[1]<br>Linseed oil | 50.0<br>25.0<br>25.0 | 4 | 18 | 16 | 2 | 88 | With spatula |
| 2 | Linseed oil<br>Lanolin<br>*Toxaphene* | 85.0<br>10.0<br>5.0 | | 24 | 0 | 24 | 0 | With brush |
| 3 | Linseed oil<br>*Toxaphene* | 95.0<br>5.0 | 2 | 33 | 0 | 33 | 0 | With brush |
| 4 | Pyrophyllite<br>*Toxaphene* | 95.0<br>5.0 | 5 | 82 | 0 | 82 | 0 | By hand |
| 5 | Pyrophyllite<br>*Toxaphene* | 80.0<br>20.0 | 1 | 9 | 0 | 9 | 0 | By hand |
| 6 | Lanolin<br>Water<br>Benzene hexachloride (10% gamma) | 81.8<br>9.1<br>9.1 | 3 | 8 | 4 | 4 | 50 | With spatula |
| 7 | Lanolin<br>Alcohol (Isopropyl 98%)<br>Water<br>Benzene hexachloride (5% gamma) | 57.0<br>22.2<br>14.5<br>6.3 | 3 | 7 | 6 | 1 | 85 | With spatula |
| | Lanolin<br>Water<br>Benzene hexachloride (10% gamma)<br>Rotenone extract (5%) | 78.3<br>8.7<br>8.7<br>4.3 | 2 | 22 | 22 | 0 | 100 | With spatula |
| 9 | Benzene hexachloride (7.5% gamma)<br>Pyrophyllite | 50.0<br>50.0 | 5 | 42 | 0 | 42 | 0 | By hand |
| 10 | Pyrophyllite<br>Benzene hexachloride (7.5% gamma) | 86.7<br>13.3 | 11 | 49 | 0 | 49 | 0 | By hand |
| 11 | Linseed oil<br>Rotenone extract (5%) | 91.4<br>8.6 | 4 | 32 | 29 | 3 | 90.6 | With brush |
| 12 | Linseed oil<br>Rotenone extract (5%) | 97.0<br>3.0 | 3 | 30 | 30 | 0 | 100 | With brush |
| 13 | Fuller's earth<br>Cube (4.5% rotenone) | 66.7<br>33.3 | | 3 | 1 | 2 | 33.3 | By hand |
| 14 | Calcium carbonate<br>Cube (4.5% rotenone) | 66.7<br>33.3 | 7 | 45 | 38 | 7? | 84.4–100 | By hand |
| 15 | Calcium carbonate<br>Cube (4.5% rotenone) | 66.7<br>33.3 | 12 | Approximately 8 grubs per animal about 97% control | | | | By hand |
| 16 | Calcium carbonate<br>Cube (4.5% rotenone) | 66.7<br>33.3 | 13 | Approximately 30 grubs per animal about 97% control | | | | By hand |
| 17 | Lanolin<br>Water<br>Chlordane | 90.0<br>5.0<br>5.0 | 5 | 37 | 34 | 3 | 91.9 | With spatula |
| 18 | Linseed oil<br>Chlordane | 95.0<br>5.0 | 4 | 55 | 30 | 25 | 54.5 | With brush |
| 19 | *U. S. Screwworm Smear No. 6* | 100.0 | 1 | 8 | 0 | 8 | 0 | With spatula |
| 20 | Pyrophyllite<br>*Methoxychlor*[2] | 97.0<br>3.0 | 2 | 6 | 0 | 6 | 0 | By hand |
| 21 | Pyrophyllite<br>*Methoxychlor* | 90.0<br>10.0 | 1 | 11 | 0 | 11 | 0 | By hand |
| 22 | Lanolin<br>Linseed oil<br>O-nitrodiphenyl | 50.0<br>25.0<br>25.0 | 2 | 3 | 3 | 0 | 100 | With spatula |
| 23 | Borax | 100.0 | 2 | 5 | 0 | 5 | 0 | By hand |

[1] Chlorinated camphene.
[2] Bis (methoxyphenyl) trichloroethane.

the dust carriers was approximately 45 microns in diameter. The solutions were brushed on with a 1-inch paint brush. The ointments were applied by hand or with a spatula. In the case of the solutions and ointments only the cysts were treated. These soon became matted with dirt and other extraneous matter, so that the treated cysts could be easily located at subsequent examinations.

The lanolin ointments containing synthetic insecticides were prepared by heating the lanolin and the insecticide together until both had dissolved. The additional materials were then added, *i.e.*, water, rotenone extract, alcohol or linseed oil and the resulting mixture was stirred rapidly until cooled to room temperature. They were then ready to apply.

RESULTS AND CONCLUSIONS.—A summary of 23

trials involving 94 animals and approximately 1000 warbles is embodied in table 1. While it is realized that in some instances too few animals and warbles were involved to reach any definite conclusions regarding the efficacy of any formulation, the following indications are noted:

(1) The efficacy of certain synthetic insecticides is enhanced when they are incorporated in bases of linseed oil or lanolin, or both.
(2) Chlorinated camphene holds little promise against grubs except possibly in high concentration of ointments or solutions.
(3) Dusts of benzene hexachloride were ineffective at 1 to 3.7 per cent gamma content. Ointments at 0.3 per cent and 0.9 per cent were fair to good.
(4) Calcium carbonate appears to be a satisfactory carrier for rotenone dusts.
(5) Five per cent chlordane ointments and solutions show some promise.
(6) *Methoxychlor* dusts at 3 and 10 per cent concentrations, as well as *Screw Worm Smear No. 62* and borax were ineffective.
(7) Three grubs were treated with a 25 per cent concentration of *o*-nitrodiphenyl in linseed oil and lanolin. All were killed.

## Species and Incidence of Cattle Grubs in Oregon

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A knowledge of the species of cattle grubs, *Hypoderma*, found in an area, as well as the dates of their appearance on and disappearance from the backs of cattle, is important in advising livestock growers in insect-control operations. In many places in the West, it is range practice to winter cattle in lowland valleys, and as soon as range conditions permit in the spring to drive them to higher mountain grazing areas. Apparently cattle are often moved before all the grubs are mature, although complete evidence is not at hand to substantiate this. Inasmuch as stockmen do not usually round up the cattle again until fall, late treatments for cattle grubs are not made. Information on seasonal incidence of grubs may lead to revised schedules of treatment.

Observations and collections of grubs were made in a number of places in Oregon during the season of 1946–1947. More detailed work needs to be done, but the following observations indicate the species and incidence of the pest in this State.

Most of the observations were made in the Willamette Valley, which has a comparatively mild climate and an annual rainfall of about 40 inches. Late in the winter and early in the spring when grubs are dropping from the backs of cattle, the ground is generally wet. This wet soil apparently does not prevent sufficient grubs from emerging to be of economic importance.

A few examinations of dairy cattle during the last week in December showed that grubs were already up in the backs of cattle. A systematic semimonthly examination of approximately 150 dairy cattle on 5 farms in the vicinity of Corvallis was initiated early in January. These herds were not treated and no grubs were extracted during the course of the examinations. The results in table 1 show that as high as 63 per cent of the animals were infested in February, and that the per cent of infestation decreased gradually until July. The average number of grubs per infested animal ranged up to 8.1.

In order to determine the species of cattle grubs present, semi-monthly collections were from several herds throughout the winter and spring (Table 2). The number of grubs collected during each period ranged from 50 to 120. All the grubs collected during January were *Hypoderma lineatum* (De Vill.). The first records of *H. bovis* (Deg.) were for February 3 and 7, when a few second-instar larvae were collected. The collections during the first half of March were not so numerous as desired, but 7 per cent were *H. bovis*. After this time the percentage of this species increased until by the middle of April only *H. bovis* grubs were collected. Mills and coworkers

**Table 1.—*Hypoderma* infestations of dairy cattle on five herds in the vicinity of Corvallis, Ore., 1947.**

| Date Examined | | Per Cent of Cattle Infested | Grubs per Infested Animal Average |
|---|---|---|---|
| January | 9 | 40 | 4.1 |
| | 25 | 63 | 8.1 |
| February | 13 | 61 | 6.3 |
| | 27 | 46 | 5.0 |
| March | 11 | 36 | 6.1 |
| | 27 | 26 | 3.7 |
| April | 10 | 29 | 3.2 |
| | 24 | 21 | 1.6 |
| May | 12 | 18 | 1.4 |
| | 31 | 14 | 2.0 |
| June | 30 | 4 | 1.1 |

**Table 2.—Per cent of grubs of the two species of *Hypoderma* collected in the vicinity of Corvallis, Ore. 1947.**

| Date | | *H. bovis* | *H. lineatum* |
|---|---|---|---|
| January | 1 to 15 | 0 | 100 |
| | 16 to 31 | 0 | 100 |
| February | 1 to 14 | 3 | 97 |
| | 15 to 28 | 7 | 93 |
| March | 1 to 15 | 7 | 93 |
| | 16 to 31 | 44 | 56 |
| April | 1 to 15 | 93 | 7 |
| | 16 to 30 | 100 | 0 |
| May | 1 to 15 | 100 | 0 |
| | 16 to 31 | 100 | 0 |
| June | 1 to 15 | 100 | 0 |
| | 16 to 30 | 100 | 0 |

[1] Some of the observations in eastern Oregon were made in company with R. W. Every, extension entomologist at Oregon State College. E. W. Laake and R. W. Wells, of this Bureau identified and verified some of the *Hypoderma* collections.

(1946) show a similar seasonal trend in Montana, but *H. bovis* did not appear there until early April. Since Bishopp and coworkers (1928) show comparatively few *H. bovis* in the western United States, it is concluded that this species has become firmly established in this area during the past 20 years.

Systematic examinations of cattle in eastern Oregon could not be made, but several observations indicated that the cattle grub problem is of considerable importance in range cattle over a large part of that area. Eastern Oregon has entirely different meteorological conditions from the Willamette Valley, and is characterized by low rainfall (10 to 20 inches) and by fairly cold winters and springs. The collection data in table 3 show the results of examinations of beef cattle on widely scattered ranches in five counties in January. The per cent of infested animals ranged from 38 to 95, and the average number of grubs per infested animal was as high as 43.4 in Grant County. All the grubs collected during this period proved to be *Hypoderma lineatum*.

**Table 3.—*Hypoderma lineatum* infestations on backs of beef cattle in eastern Oregon, January 7 to 16, 1947.**

| County | Ranches Visited | Animals Examined | Per Cent of Cattle Infested | Grubs per Infested Animal (Average) |
|---|---|---|---|---|
| Gilliam | 5 | 37 | 95 | 18.1 |
| Morrow | 3 | 37 | 86 | 17.7 |
| Umatilla | 5 | 52 | 60 | 5.5 |
| Grant | 5 | 46 | 87 | 43.4 |
| Crook | 3 | 42 | 38 | 12.5 |

A survey through some of these counties on April 16 to 19 showed that practically all the cattle had been moved to summer ranges. A few examinations of cattle still remaining in the valleys showed a lower grub population than during January. Of the grubs collected, 74 per cent were *Hypoderma bovis*. It would be highly desirable to make examinations of cattle during May which are being pastured on high summer ranges in order to determine the last date when grubs are present.

From March 31 to April 4, 158 beef cattle were examined in Lake, Crook, and Harney Counties in south-central Oregon. The average percentage of infested animals in these counties ranged from 53 to 60. In Lake County 7.7 grubs per infested animal were recorded. The observations in the other 2 counties indicated that most of the grubs had recently dropped from the cattle. In the Lake County collections 99 per cent of the grubs were *Hypoderma bovis*. Of the 26 grubs collected in Harney County, all were *H. lineatum*.

In northern Klamath County, which adjoins Lake County, collections on June 14 showed that 94 per cent of the beef cattle were infested with *Hypoderma bovis*.

Information on the grub incidence along the coastal areas of Oregon is far from complete. In these coastal areas the rainfall may reach 100 inches annually, and there is considerable cloudy weather. The climate differs markedly from that in eastern Oregon. Examinations of a few dairy herds near Florence along the central coast in February showed from 70 to 100 per cent of the animals to be infested. The average number of grubs per infested animal was 11. All the grubs collected were *Hypoderma lineatum*.

On May 1 and 2 several collections along the northern coast of Oregon in Tillamook County showed 91 per cent of the grubs to be *Hypoderma lineatum*. At the same time collections further inland in Yamhill, Polk, Washington, and Columbia Counties proved to be 100 per cent *H. bovis*. The percentage of infested animals in all of these counties ranged from 8 to 43.

The information accumulated indicates that the cattle grub is a widespread pest in Oregon, and that often 100 per cent of the cattle may be infested. The presence of both species of *Hypoderma* makes a rather long grub season.

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**Bishopp, F. C.,** E. W. Laake, H. M. Brundrett, and R. W. Wells. 1926. The cattle grubs or ox warbles, their biologies and suggestions for control. U. S. Dept. Agr. Bul. **1369.**

## The Beet Armyworm on Flax

J. N. Roney, *University of Arizona, Phoenix*

Late in February, 1947, County Agent Robert J. Moody, of Yuma County, Arizona, contacted me about an insect that was feeding on the upper portion of flax plants that were blooming rather prolifically. At the first description it was thought that possibly the insect was the cotton bollworm, *Heliothis armigera*. However, when field examinations were made, it was found that it was the common beet armyworm, *Laphygma exigua*. I say the common beet armyworm due to the fact that in Arizona this insect is often present on cotton and alfalfa.

Generally speaking, the insect is kept in check by the presence of parasites and predaceous enemies. This insect very seldom causes any injury to cotton in Arizona unless the first generation escapes being parasitized or destroyed by predaceous enemies. Sometimes it causes injury to cotton late in the season.

During 1946, a heavy outbreak of the insect occurred on cotton in Pinal County, Arizona. The infestation appeared when the cotton was in the seeding stage and there was a chance the crop would be destroyed unless it was controlled. At the suggestion of the Bureau of Entomology and Plant Quarantine, Division of Cotton Insects, an application of a 5 per cent DDT dust, 20 pounds per acre, was made and the insects were controlled.

A complete examination of the flax fields in Yuma County showed that the larvae of the beet armyworm were present in all fields. We also found great numbers present feeding on the tops of the plants thus destroying the fruiting portion. In many places we were able to count as many as 25 to 40 larvae per square yard. This picture gives one an idea of just how much injury the larvae might have caused if they have not been controlled. Examinations of several fields in the lower Yuma valley showed this insect present in practically all of the fields. It was very evident that unless something was done at once the flax growers stood a chance of losing a crop,

and with the price of flax very high, the farmers were greatly concerned. It was decided that since the 5 per cent DDT dust had worked so well on cotton it would be wise to use this same material for the control of this same insect when feeding on flax. It was suggested that the farmers use 20 pounds of a 5 per cent DDT dust with an inert carrier to be applied when weather conditions allowed. Since the flax was so far advanced, airplane dusting was the only practical method of applying the insecticide. One application of this dust gave complete control of the insects and saved a very valuable crop.

The beet armyworm was also present in flax in the Imperial valley of California and was controlled in the same manner.

In Maricopa County, close observations were kept of flax fields but infestations never developed. Several farmers in Maricopa County dusted upon the advice of some persons who were not qualified to make recommendations, and thus threw their money away. It is thought that the natural enemies kept the flax insect populations down to their normal numbers in Maricopa County, therefore, we did not have any injurious infestations to combat.

From the observations made in Arizona during 1947, it is very evident that this insect can be a major pest of the flax industry unless control measures are applied promptly. The Extension Entomologist in Arizona has been greatly helped on insect problems by the keen observations of the County Agents.—7-20-47.

## Chlordane for Control of Japanese Bettle Larvae in Turf*

WALTER E. FLEMING, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In a study of soil fumigants preliminary tests by A. C. Mason and R. D. Chisolm in the spring of 1946 indicated that an emulsion of chlordane and ethylene dichloride was highly effective but slower than an emulsion of ethylene dibromide and ethylene dichloride in killing larvae of the Japanese beetle, *Popillia japonica* Newm.

Experiments were begun by the writer in January 1947 to determine the value of chlordane alone for control of the larvae in turf. A preliminary report of the results obtained up to this time is given in this paper.

LABORATORY TESTS.—Technical chlordane was first tested in the laboratory in comparison with DDT. It was used as a 1-per cent dust, intimately mixed with sassafras sandy loam, at rates equivalent to 0.25, 0.5, 1, 2, 5, 10, 25, 50, 100, and 200 pounds chlordane per acre. DDT was used as a 10 per cent dust, mixed with soil, at rates equivalent to 10, 25, and 50 pounds of DDT per acre. One hundred and fifty third-instar larvae were introduced into each lot of treated soil immediately after application of the materials, and 4 and 8 weeks later. In each case larval mortality was determined at weekly intervals. When freshly applied, 1 pound of chlordane per acre appeared to be as effective as 25 pounds of DDT. After being in the soil for 4 weeks chlordane appeared as effective as when freshly applied, but after 8 weeks it seemed to be slightly less effective. At this time 2 pounds of chlordane were required to give results equal to those obtained with 25 pounds of DDT.

FIELD TESTS.—In May technical chlordane was applied as a 5 per cent dust to the surface of four 0.25 acre plots of turf at the rate of 10 pounds chlordane per acre by means of a 3-foot fertilizer spreader. Two of these plots were at Blairstown, N. J., and the others were at Orange and New London, Conn.[1] At the same time 10 per cent DDT was applied at the rate of 25 pounds DDT per acre in a similar manner to comparable plots at each location. Larval surveys of the plots were made 4 and 17 weeks later to determine the effect of each treatment. Each survey involved taking 15 separate square-foot diggings to a depth of 4 inches in each treated plot and 50 diggings in untreated turf around the plots at each locality. The results of these surveys are summarized in table 1.

**Table 1.—Comparative effectiveness of 10 pounds of technical chlordane and 25 pounds of DDT per acre against Japanese beetle larvae.**

| Location of Plots | Number of Larvae Per Square Foot in Untreated Turf | Apparent Per Cent Reduction in Treated Turf | |
|---|---|---|---|
| | | Chlordane | DDT |
| 4 Weeks after Application—1946–7 Brood | | | |
| Blairstown, N. J. | 14.6 | 96.4 | 83.5 |
| | | 91.3 | 72.6 |
| Orange, Conn. | 7.6 | 96.6 | 75.4 |
| New London, Conn. | 9.8 | 96.3 | 10.2 |
| | Av. | 95.2 | 60.4 |
| 17 Weeks after Application—1947–8 Brood | | | |
| Blairstown, N. J. | 18.7 | 99.6 | 99.6 |
| | | 100.0 | 100.0 |
| Orange, Conn. | 23.8 | 100.0 | 99.4 |
| New London, Conn. | 8.6 | 100.0 | 54.6 |
| | Av. | 99.9 | 88.4 |

The chlordane reduced the population more rapidly than did the DDT and retained sufficient residual effectiveness in the soil practically to eliminate the subsequent brood by mid-September.

The condition of the turf and the feeding habits of the larvae at New London were different from those at the other locations. At Blairstown and Orange relatively shallow-rooted grasses predominated, and practically all the larvae were within 1 inch of the surface; at New London the turf was composed of deep-rooted grasses with a dense mat at the surface and the larvae were found as much as 3 inches below the surface. Under the conditions at New London it was evident that chlordane penetrated sufficiently well into the soil to kill a high proportion of the larvae and that DDT did not. This result suggests that chlordane may be expected to give effective control quickly under a wider range of conditions than DDT.

In view of the favorable results obtained with an application of chlordane in the spring, additional treatments were made late in September, while the larvae were still near the surface. At Northampton, Mass., chlordane was applied as a 5 per cent dust to 0.15 acre of turf at the rate of 10 pounds chlordane

* Paid Paper.

[1] The work in Connecticut was carried out in cooperation with J. C. Schread, of the Connecticut Agricultural Experiment Station.

per acre. After 17 to 18 days the larval population had decreased from 20 to 1.4 per square foot, or 93 per cent. At Deerfield, Mass., 56 acres of turf, with an average population of 134 grubs per square foot, were sprayed with chlordane at the rate of 10 pounds per acre (20 pounds of 50 per cent wettable powder in 1,200 gallons of water). Within 17 or 18 days, the population was reduced to 9.6 per square foot. or 93 per cent. No rain followed these treatments, The results indicate that in the fall, as in the spring, chlordane was highly effective against Japanese beetle larvae. They further indicate that it was equally effective whether applied as a dust or as a spray to the surface of turf.

EFFECT OF CHLORDANE ON GRASS.—In laboratory tests established turf of various grasses and clover was sprayed with chlordane at the rate of 25 pounds per acre (50 pounds of 50 per cent wettable powder per 1000 gallons of water), 2.5 times the rate used for control of larvae. At intervals after treatment the grass was cut and weighed. The chlordane had no effect on the color, general appearance, or growth of the following grasses: redtop, Colonial bentgrass, Astoria bentgrass, Bermuda grass, orchard grass, meadow fescue, Chewings fescue, perennial ryegrass, Canada bluegrass, Kentucky bluegrass, and rough, stalk bluegrass. In addition to these grasses, white clover grew normally.

At Blairstown, Orange, New London, Northampton, and Deerfield there was no indication that the application of chlordane at the rate of 10 pounds per acre had any adverse effect on the various grasses and clover.—12-8-47.

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## Piperonyl Cyclonene and Piperonyl Butoxide as Synergists with Rotonene*

LOYD W. BRANNON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

In a previous paper Brannon (1946) reported the results of experiments in which significant control of the Mexican bean beetle, *Epilachna varivestis* Muls., and the corn earworm, *Heliothis armigera* (Hbn.), on fall crop snap beans was obtained with a commercial dust mixture containing 0.04 per cent of pyrethrins and 0.5 per cent of piperonyl cyclonene (formerly designated as Piperonyl Cyclohexenone). In other experiments during 1946 the author obtained from 52 to 77 per cent control of the Mexican bean beetle with a dust mixture containing 0.5 per cent of piperonyl cyclonene in pyrophyllite. Dove (1947) mentions the effectiveness of piperonyl butoxide in the control of the Mexican bean beetle.

In 1947 two experiments were conducted at Norfolk, Virginia, to determine the effectiveness against the Mexican bean beetle of low-strength rotenone dusts to which either piperonyl cyclonene or piperonyl butoxide was added. The experiments were conducted on Bountiful snap beans in plots 4 rows wide and 36 feet long arranged in randomized blocks, so that each treatment occurred once within each block. Each block contained also one undusted plot. The dusts were applied with bellows-type hand dusters, applications being made from each side of the row so that the under surfaces of the leaves were covered.

Commercial materials used in preparing the dust mixtures were cube root powder (rotenone 3.6 per cent, total extractives 13.5 per cent), 2.5 per cent piperonyl cyclonene on walnut-shell flour, 5 per cent crude piperonyl butoxide on walnut-shell flour, and 51.5 per cent DDT. Pyrophyllite was used as the diluent for these materials except where sulfur has been indicated.

In the first experiment applications of the various dusts were made on June 4, 12, and 25. Four days after the first application 0.07 inch of rain fell, 0.3 inch fell 33 hours after the second application, and 0.22 inch fell 24 hours after the third. At the time of the first application the plants contained first and second trifoliate leaves, and at the time of the third they were blooming and beginning to form small pods. Counts of Mexican bean beetles made on the four random undusted plots just prior to the first application indicated an average infestation of 4 beetles, 4 egg masses, and 3 batches of young larvae on 6 feet of row.

As shown in table 1, the mixtures containing 0.22 per cent of rotenone with each of the piperonyl materials were as effective against the larvae of the Mexican bean beetle as a dust mixture containing twice this strength of rotenone plus DDT and sulfur. The rotenone-DDT mixture, however, was the most effective against the adults.

In the second experiment dust mixtures were applied on July 15, 21, and 28 and on August 5. It rained shortly after each application, the precipitation being 0.17, 1.27, and 0.14 inches within 10 hours after the first, second, and third applications, respectively, and 0.85 inches about 38 hours after the fourth application.

Under conditions of unusually heavy infestations of the Mexican bean beetle and extremely adverse weather, the addition of 0.5 per cent of piperonyl cyclonene to cube root dust reduced in strength to contain only 0.125 per cent of rotenone gave control of the Mexican bean beetle comparable to that obtained with the recommended 0.5 per cent rotenone dust. Increases of 64 and 65 bushels of marketable beans per acre over the undusted plots were obtained with the two mixtures. When piperonyl butoxide was substituted for piperonyl cyclonene, a greater number of larvae survived and the increase in yield was only 41 bushels per acre. The mixture containing 0.125 per cent of rotenone without either of the piperonyl compounds was ineffective.

Incidental to the foregoing experiments, limited tests were made with the piperonyl materials without the presence of other insecticides. At the 0.5 per cent strength the effect on larvae and pupae of the Mexican bean beetle was within the limits of experimental error. In other words, the tests did not substantiate those of 1946, in which 0.5 per cent piperonyl cyclonene gave 77 per cent control of larvae and pupae in one experiment and 52 per cent in another. This difference in effectiveness may have been due to the formulations employed. In 1946 the dust was prepared by the author by spraying onto pyrophyllite a solution of piperonyl cyclonene in an equal volume of acetone. In 1947 commercial preparations of 2.5 per cent of piperonyl cyclonene and of piperonyl butoxide on walnut-shell flour were diluted with pyrophyllite.

These preliminary experiments at Norfolk, Va., under conditions existing in 1947 indicate that either piperonyl cyclonene or piperonyl butoxide has a

* Paid Paper.

[1] In cooperation with the Virginia Truck Experiment Station.

**Table 1.—Effectiveness of piperonyl cyclonene or piperonyl butoxide with rotenone against the Mexican bean beetle.**

| Dust Mixtures | Rate per Acre | Yield per Acre[1] | Adults on 6 Feet of Row[2] | Larvae and Pupae Surviving on 10 Plants[3] | Control of Larvae |
|---|---|---|---|---|---|
| (*Per cent by Weight of Ingredients in Pyrophyllite*) | *Pounds* | *Bushels* | *Number* | *Number* | *Per cent* |
| | | | Experiment 1 | | |
| Rotenone 0.22, piperonyl butoxide 0.5 | 26 | — | 4.5 | 2 | 96 |
| Rotenone 0.45, DDT 3, sulfur 50 | 23 | — | 1.7 | 4 | 92 |
| Rotenone 0.22, piperonyl cyclonene 0.5 | 23 | — | 6.0 | 4 | 92 |
| Check (untreated) | — | — | 8.2 | 50 | — |
| Difference required for significance (odds 19:1) | — | — | 1.5 | 8 | — |
| | | | Experiment 2 | | |
| Rotenone 0.125, piperonyl cyclonene 0.5, sulfur 25 | 20 | 167 | — | 5 | 98 |
| Rotenone 0.5, DDT 3, sulfur 50 | 23 | 168 | — | 11 | 96 |
| Rotenone 0.125, piperonyl butoxide 0.5, sulfur 25 | 21 | 144 | — | 35 | 86 |
| Rotenone 0.125, sulfur 25 | 20 | 101 | — | 263 | — |
| Check (untreated) | — | 103 | — | 253 | — |
| Difference required for significance (odds 19:1) | — | — | — | 47 | — |

[1] The beans were picked August 18, and September 2, 1947.
[2] 24 hours after first application.
[3] 5 days after the last application in experiment 1 and 11 days after the last application in experiment 2.

synergistic effect when used with low-strength rotenone dust mixtures against the Mexican bean beetle.

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## DDT and the Woolly Apple Aphid Parasite *Aphelinus mali*

M. A. Yothers, U. S. D. A., *Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The use of DDT for the control of the codling moth *Carpocapsa pomonella* (L.) and other apple insects now appears to interfere in some manner with the activity of *Aphelinus mali* (Hald.), the most important parasite of the woolly apple aphid, *Eriosoma lanigerum* Hausm. Where DDT insecticides are used in the Pacific Northwest the parasite is no longer able to keep its host under control, and again the aphid threatens to become a destructive pest that will require the application of sprays for its control. The findings of Newcomer *et al.* (1946) on this effect of DDT sprays on the woolly apple aphid and on *Aphelinus* have been substantiated by numerous other workers.

Although *Aphelinus mali* attacks several other species of aphids, it has come to be known chiefly as the woolly apple aphid parasite, because of its special effectiveness on that pest. It was not until the Bureau of Entomology of the United States Department of Agriculture made shipments of this parasite to France, New Zealand, South Africa, and Uruguay in 1920–21 (Howard 1929), and in the following years to many other countries, resulting in its rapid and effective establishment, that it became known as an outstanding example of biological control. It was eventually introduced into most of the apple-growing countries of the world. In many of these it has effectively controlled the woolly apple aphid, and in some it has so reduced the aphid population that the use of sprays for its control has become unnecessary. This has been particularly true in the Pacific Northwest. In this district the woolly aphid is intimately associated with perennial canker of the apple, caused by *Gloeosporium perennans* Zeller & Childs. It now appears highly probable that wherever DDT is used in orchards where *Aphelinus mali* has heretofore given substantial control, the usefulness of this parasite will be, at least temporarily, greatly reduced. 10-1-47.

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JOURNAL OF ECONOMIC ENTOMOLOGY

*Official Organ American Association of Economic Entomologists*

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# *Publication Problems*

Members of the Association have been more than considerate of the editor in the difficulties encountered in the publication of the Journal during the war years and the period following. At the same time they have become justifiably concerned with the belated appearance of the various issues of the Journal during the past year or two.

It is true that some of this has been due to shortages of labor and materials which have confronted the printers but it is equally true that much of the delay has not resulted from these causes and this fact should, in fairness to the printers, be known to the readers.

During the war period there was a steady decline in the amount of material submitted for publication. Had it not been for the discovery of DDT and the resulting reports of its value as an insecticide it is extremely doubtful if we should have been able to continue publication of the six annual issues of the size called for in our contract with the printers. And, in spite of the DDT contributions the editor had, at the time of the Dallas Meetings in December, 1945, not enough material to make up the December issue. Copy for that number was, for this reason, sent to the printers at about the time the issue was scheduled to be ready for delivery. December was consequently very late. Material for the February issue was also much retarded. Consequently, the publication schedule for 1946 was several weeks late.

Undue delay of the material for the proceedings of the Richmond meetings resulting in large part from the delay in securing reports of the various committees, held back the February, 1947, issue as copy for this in complete form could not be sent to the printers until well along in March at which time they should have had, rather, the copy for April. The 1947 volume was therefore, off to a very bad start. Some further delay was caused by the necessary absence from his office of the editor early in the summer. The results, expressed in time of receipt of the Journal, are known to all subscribers.

However, by the cooperation of the printers, some of the lost ground has been made up. The October issue was delivered in December, only about a month later than its average delivery date over a ten-year period. The December issue, at the same time, was through the galley-proof stage. Indexing necessarily delays the December issue under normal conditions but it may be expected to appear some weeks earlier than was the case in 1947.

Copy for the February issue, less the reports from the Chicago meetings, is in the hands of the printers. The reports are expected to be prompt and the February issue may reasonably be expected to appear not much later than the normal time. This is, so far as the records show, near the end of March. The last February number under the previous editor was received on March 29, 1939. In his inexperience the new editor thought that was too late and resolved to beat that record. The result was delivery of the Journal for February, 1940, on March 30.

If we can hold the gains we have made it is reasonable to hope that the 1948 Journal should be on much the schedule as in pre-war years but our efforts shall be directed toward the improvement of that schedule as rapidly as possible.

If, as is entirely probable, some of our delays have been due to delays in printing, we must still admit that the major delays have been the result of other causes. Certainly we are convinced that the printers' delays have not been caused by any lack of cooperation on their part but to factors beyond their control.

The foregoing deals with delay in the

appearance of the various numbers of the Journal. This explains the delay in appearance of some of the individual papers but it should be known that getting back onto a prompt printing schedule will not cure all delays so far as individual papers are concerned. If we are to expect cooperation from the printers we, in turn, must cooperate with them. We must furnish them copy promptly, certainly, and by implication in our contract which calls for six issues annually, we should furnish six reasonably equal installments of our material for the year rather than some overlarge lots and other correspondingly small lots. But it so happens that entomological work is seasonal, much more being done during the summer than during the winter. As a consequence approximately two thirds of the papers reach the editor in a period of four or five months and the other third is spread over at least seven months. Some inequality of the issues is permissible which tends to smooth off the peak but this can not entirely accomplish it. So, inevitably, some papers will wait longer for publication than others.

To illustrate, the February issue will include papers received, for the most part, by the first of December. April is filled by the Eastern Branch material much of which would have had priority for February publication. This will ordinarily make a full issue. Papers from the annual meeting must necessarily wait until June and carry over, in many cases, until August. Accessions from about the first of February on through the summer will appear in August and October and late summer material will occupy the December issue. Papers which are delayed in review or for other individual reasons may be one issue later that the above schedule would suggest.

Every effort will be made and is being made, to reduce the delays in the appearance of the issues of the Journal and to secure the most prompt publication possible for the individual papers. We confidently predict some improvement but there will still be aggravating delays at the best. And there is no doubt that some of these will be the fault of the editor alone, in the future as in the past.

## Rocky Mountain Conference of Entomologists
### Cameron Pass Camp, Colorado
### August 17–21, 1947

The eighteenth Rocky Mountain Conference of Entomologists was held at the Cameron Pass Camp Aug. 17 to 21, 1947. This camp is located in the mountains at an altitude of about 9500 feet, 80 miles west of Fort Collins, Colo. Camp was made during the afternoon of the 17th and was broken during the morning of the 21st. Three full days were available for discussions and recreation. A total of 7 discussion meetings were held. Due to war conditions this was the first meeting of the Conference since 1941. Those who were directly interested in entomology represented 16 states. Members of the families made a total registration of 102.

The entomologists were:

Bigger, John
Bonnell, D. E.
Buchanan, W. D.
Burnside, W. H.
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Tanner, Vasco M.
White, J. F.
Wygant, N. D.

A program committee consisting of Ephriam Hixson, W. E. McCauley, and H. H. Ross arranged the subjects which had been suggested into related groups. All meetings were of the roundtable type. The general topics and the principal speakers under each were as follows, the first named person acting as the discussion leaders.

*Livestock insect pests:*
Ephriam Hixon, D. E. Howell, Thomas Snipes, T. R. Robb, D. G. Denning, Claine E. Titensor and M. T. James.

*Forest insect problems:*
Noel Wygant, Calvin Massey, W. D. Buchanan and H. F. Gates.

*Fruit insects:*
A. Flebut, Stanley Flanders, J. H. Newton, Geo. M. List, W. E. McCauley, Fred Fletcher.

*Biological control of insects in California:*
(Illustrated) Stanley Flanders

*Field crop pests:*
W. E. McCauley, Thomas Snipes, J. H. Bigger, Ephriam Hixon, J. R. Douglass.

*Insect toxemia and virus relationships:*
Geo. M. List and L. B. Daniels.

*Truck crop pests:*
Fred F. Fletcher, J. R. Douglass, L. B. Daniels, C. E. Nelson, Jr., C. C. Compton, J. E. Bussart, Thomas Snipes, A. Flebut and Ephriam Hixson.

*Insect taxonomy and related topics:*
V. M. Tanner, Miriam A. Palmer, Kathleen C. Doering, F. M. Hull, H. H. Ross, D. Elmo Hardy.

*Beekeeping problems:*
V. G. Milum and L. M. Gates.

The weather was good, insect collecting good and fishing fair.

The officers elected to arrange for the 1948 Conference were:

L. B. Daniels, *Chairman*
L. M. Gates, *Vice-Chairman*
Geo. M. List, *Secretary*
J. L. Hoerner, *Treasurer*

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*Secretary*

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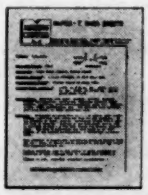

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   32½% by volume Deodorized Kerosene.
   5% by volume of an oil-soluble non-alkaline emulsifier.
   Each pint of this concentrate contains 1 lb. of "VELSICOL" "1068" TECHNICAL.
2. Use of "VELSICOL" "1068" with water and emulsifier.

**WETTABLE POWDERS**

These are readily made by the use of 3% of a good wettable agent with a 50-50 mix by weight of "VELSICOL" "1068" TECHNICAL and an absorptive carrier.

**INSECTICIDAL DUSTS**

Up to 5% by weight on non-absorptive powders such as talc or pyrophyllite.
Up to 50% by weight on absorptive powders such as diatomaceous earth or fossil flour.
Makes excellent uniform dusts with good physical properties.

In the extensive experimental work which has been conducted to date in agriculture with effective formulations of "VELSICOL" "1068" there has been no record of plant injury due to the compound $C_{10}H_6Cl_8$. This indicates that "VELSICOL" "1068" is safe to use on vegetative crops.

For details of the agricultural applications of this effective insect toxicant—write today for your copy of Technical Information Bulletin No. 205.

# VELSICOL Corporation

*Manufacturers of: Insect Toxicants • Aromatic Solvents • Coresin Core Oils • Synthetic Resins*

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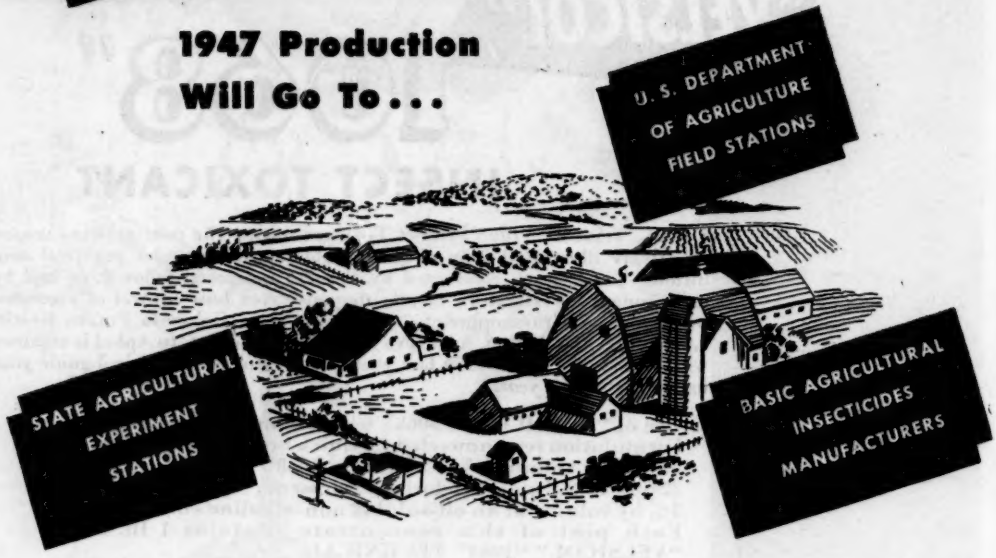
**J. E. Russel, Houston 11 • Geo. Missbach & Co., Atlanta 3 • Natural Products, Montreal, Canada**

DISTRIBUTION POLICY FOR HERCULES

# TOXAPHENE

*(chlorinated camphene)*

**1947 Production Will Go To . . .**


U. S. DEPARTMENT OF AGRICULTURE FIELD STATIONS
STATE AGRICULTURAL EXPERIMENT STATIONS
BASIC AGRICULTURAL INSECTICIDES MANUFACTURERS

DURING 1947, Toxaphene* (chlorinated camphene) will be in limited supply and will be allotted as shown above. Distributors, dealers, and growers are requested to obtain finished and semi-finished Toxaphene concentrates from their regular agricultural insecticide manufacturers.

Federal, state, and other qualified scientists are running extensive field tests with this promising insecticide toxicant. Results, to date, indicate that Toxaphene is highly effective against cotton insects, the Mexican bean beetle, the sugarcane borer, grasshoppers, and other insects that plague the farmer.

Watch for further news of test results and distribution data on Toxaphene.

HERCULES POWDER COMPANY

INCORPORATED

*991 Market Street, Wilmington 99, Delaware*

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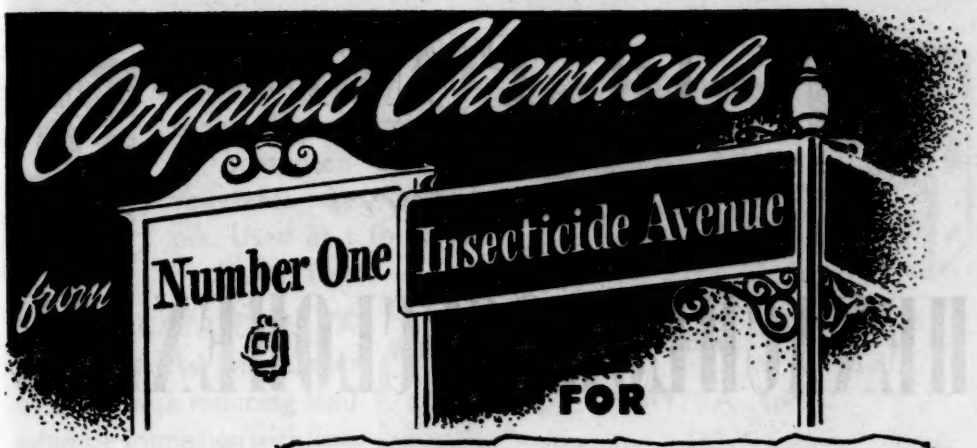


**INSECTICIDE MANUFACTURERS**
**RODENTICIDE MANUFACTURERS**
**HERBICIDE MANUFACTURERS**

☐ **DDT PRODUCTS**

DDT concentrates for every purpose.
*JP 10*—A DDT powdered insecticide containing 10% of technical DDT W/w and 90% of Sesaminized Pyrethrum Marc.
*JP 25*—A liquid, water miscible DDT spray concentrate containing 25% of technical DDT W/w with hydrocarbon solvent.
*JP 30*—A liquid, oil soluble DDT concentrate containing 30% of technical DDT W/w and 70% of a special hydrocarbon solvent.
*JP 50*—A micron sized DDT dust concentrate containing 50% of technical DDT W/w for use in manufacture of finished insecticide dusts.
*JP 50W*—A wettable DDT powder concentrate containing 50% of technical DDT W/w for mixing with water to make a finished product.

☐ **RODENTICIDE**

*Antu*—A new, economical, effective, highly-toxic rodenticide which is extremely acceptable to rats and non-irritating to the skin. Can be used with standard baits, on animal drinking cups or as a tracking poison. Concentrated or 20% dust.

☐ **BOTANICALS**

Pyrethrum — Rotenone — Sabadilla — Pyrethrum Extracts.

☐ **AEROSOL FORMULAS**

Powell pioneered aerosol formulas, sent some of the first to be used by the armed forces. Let Powell help you solve your aerosol problems.

☐ **HERBICIDES**

*2,4-D* in four Powco formulations. Powell conducted a year's research before offering these products to manufacturers. It will pay you to investigate these Powco Brand 2,4-dichlorophenoxyacetic acid concentrates. Let us solve your weed control problem.

☐ **NEW PRODUCTS**

*BHC* (Benzene hexachloride)—a new concentrate for control of a wide range of agricultural pests. Controls cotton insects, aphids, grasshoppers, etc.

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EVERY POWCO PRODUCT
BIOLOGICALLY TESTED AND
CHEMICALLY STANDARDIZED

# DU PONT

*Announces*

# HEXACHLOROCYCLOHEXANE

## Another Forward Development in Insecticides

HEXACHLOROCYCLOHEXANE is a new and outstanding insecticide. In the annual Hurter Memorial Lecture, delivered on March 8, 1945, by Dr. R. E. Slade, Research Controller of Imperial Chemical Industries, he stated, "There has now come to light what promises to be one of science's important contributions to the welfare of man." Dr. Slade referred to Hexachlorocyclohexane which was developed as an insecticide by Imperial Chemical Industries under the following additional names: benzene hexachloride, 666, and Gammexane.

Du Pont has confirmed the British records of efficiency of this remarkable insecticide in its own laboratories, and is privileged to announce it has Hexachlorocyclohexane available this season in limited quantities for experimental use. Inquiries from research institutions and qualified investigators are invited; a copy of Dr. Slade's lecture will be mailed on request. Grasselli Chemicals Department, E. I. du Pont de Nemours & Company (Inc.), Wilmington 98, Delaware.

DU PONT

REG. U. S. PAT. OFF.

**BETTER THINGS FOR BETTER LIVING**

***...THROUGH CHEMISTRY***

SCALECIDE. The safest dormant oil spray in use today. The only miscible oil composed of both vegetable and mineral oils. Used at 1 to 15 for deciduous trees.

SPRAY CATALIZER. A spreader, sticker and safener of sulfur base reducing lead sulphide formation with lime sulfur or Sulfocide and arsenate of lead. Does not deteriorate.

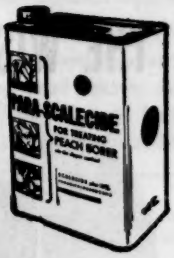
SULFOCIDE. A highly concentrated liquid sulfur fungicide, which precipitates true colloidal sulfur when drying. Not compatible with arsenical residue.

D-X ROTENONE. A rotenone contact spray in the well-known patented D-X base for garden use.

D-X NICOTINE. A nicotine contact spray in the D-X base for sucking insects, and having the impressive property of increasing the toxicity of arsenate of lead against difficult chewing insects.

SPRA-CREAM. A refined, stabilized 83% lubricating oil emulsion for dormant spraying.

PARA-SCALECIDE. A prepared combination of Scalecide and paradichlorbenzene for use in liquid treatment against peach borers. Also used for injection.




D-X SPRAY. A spray containing 1% rotenone, .37% pyrethrins and 5% DDT in an active vegetable oil base for control of sucking and chewing insects. Compatible with arsenate of lead and standard fungicides.

PRATT'S 25% DDT. A soluble DDT in an active vegetable oil base. Compatible with arsenate of lead, other poisons and standard fungicides.

PRATT'S 50% DDT. A micronized* dry wettable 50% DDT powder that mixes readily and shows no tendency to agglomerate in spray tank. May also be used as a dust when mixed in proper proportions of talc or pyrophyllite.

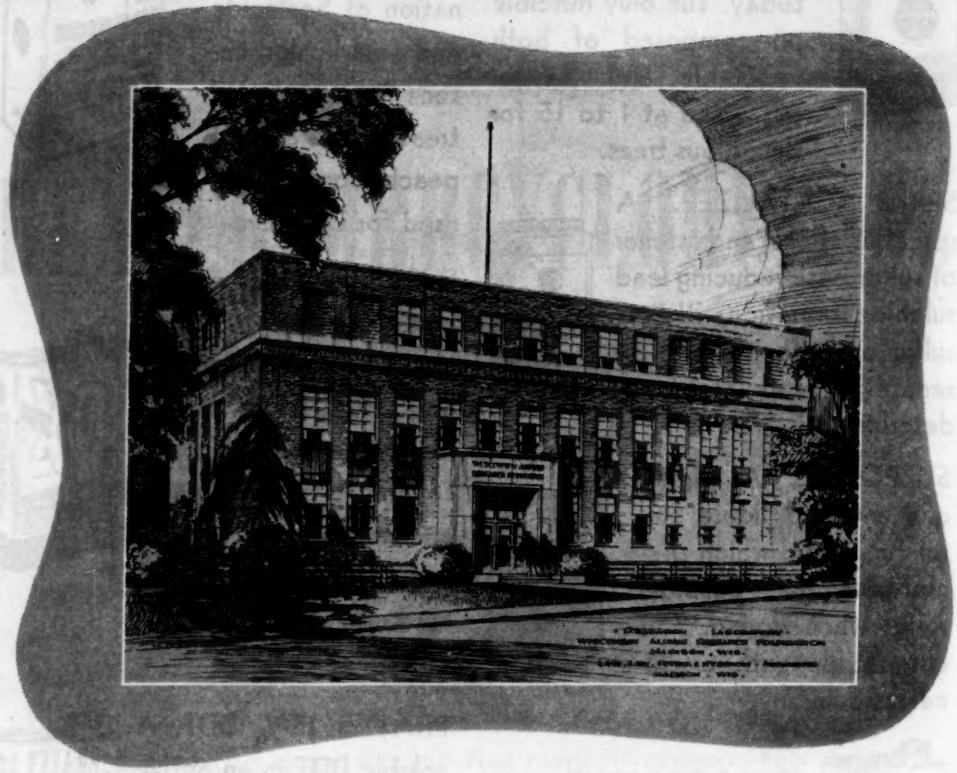
* Trade Mark Reg. by Micronizer Processing Co.

LINSO SOAP. A liquid soap of linseed oil base, without disagreeable odor, for use as a spreader.

**B. G. PRATT COMPANY**

Manufacturing Chemists
160 Moore St., Hackensack, N.J

# THE WISCONSIN ALUMNI RESEARCH FOUNDATION



## *Announces The Services Of Its*

# INSECTICIDE TESTING LABORATORY

## for the Biological Evaluation of Agricultural and Household Insecticides

- To insecticide dealers, the chemical industry and others interested in the insecticide field, our laboratory offers selective bioassay procedure for various toxicants and biological standardization through periodic testing. The functions of our testing laboratory include:
- EVALUATION OF PROPRIETARY HOUSEHOLD INSECTICIDAL MATERIALS
- DETERMINATION OF POTENCY OF PROPRIETARY AGRICULTURAL DUST AND SPRAY MATERIALS
- SCREENING OF UNKNOWN COMPOUNDS
- MISCELLANEOUS INSECTICIDE SERVICES
- In addition to this insecticidal work the Foundation offers a variety of other laboratory services. We invite your inquiries.

# WISCONSIN ALUMNI RESEARCH FOUNDATION

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AT MENASHA, WISCONSIN

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